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TNO report

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Analysis methods and models for small unit operations

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Analyse methoden en modellen voor kleine uitgestegen eenheden

Dit onderzoek gaat na in hoeverre TNO beschikt over methoden en modellen voor de analyse van operationele effectiviteit van kleine uitgestegen eenheden. Dit inzicht wordt in andere studies gebruikt om aan te geven welke op welke wijze operationele effectiviteit kan worden gekwalificeerd en gekwantificeerd.

Probleemstelling

Het doel van het project 'Meetmethoden' binnen het programma Optreden Kleine Eenheden is het inzichtelijk maken voor de Nederlandse krijgsmacht van methoden die praktisch toepasbaar zijn voor het meten en beoordelen van de inzet en het effect van een optreden van een kleine eenheid.

Beschrijving van de werkzaamheden

Er is gestart met een inventarisatie van beschikbare meetmethoden en modellen binnen TNO Defensie en Veiligheid. Door gebruik te maken van de eerder vastgestelde lijst met taken van een kleine eenheid in het project 'Small unit tactics in peace keeping operations', is per beschikbaar model en methode vastgesteld in hoeverre deze toepasbaar en relevant is om iets over de uitvoering en/of de opbrengst van deze taken vast te stellen.

Resultaten en conclusies

De studie laat zien dat, hoewel TNO beschikt over een reeks van modellen en methodieken, niet alle taken van een kleine eenheid kunnen worden beoordeeld (op onder andere hun effectiviteit). Het zijn vooral de taken in het lage geweldspectrum waarin de methodieken en modellen (nog) niet zijn toegepast en getoetst op hun bruikbaarheid. Een aantal van deze modellen en methodieken is potentieel wel bruikbaar.

Toepasbaarheid

De resultaten van deze studie dragen bij aan het maken van een overzicht van de kennis, kunde en infrastructuur ten behoeve van het programma Optreden Kleine Eenheden. De inzichten van deze studie worden gebruikt in een case-studie van het programma OKE waarin op een aanschouwelijke manier wordt zichtbaar gemaakt hoe het optreden van een kleine eenheid kan worden geoptimaliseerd en dat deze effectiviteitverbetering ook gekwantificeerd kan worden.

Analyse methoden en modellen voor kleine uitgestegen eenheden

PROGRAMMA	PROJECT
Programmabegeleider Lkol H.J.R. Oerlemans, KCGM	Projectbegeleider -
Programmaleider drs. R.G.W. Gouweleeuw, TNO Defensie en Veiligheid	Projectleider dr. A.J. van Vliet, TNO Defensie en Veiligheid
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Samenvatting

De doelstelling die ten grondslag ligt aan het onderzoeksprogramma Optreden Kleine Eenheden (OKE) is dat de Nederlandse Krijgsmacht moet kunnen beschikken over adequaat ingerichte en uitgeruste eenheden die taken in het gehele scala aan vredesondersteunende operaties, met een wisselend geweldsniveau, aantoonbaar doeltreffend en doelmatig moeten kunnen uitvoeren. Bij de uitvoering van vredesondersteunende operaties ligt de nadruk op het optreden van kleinere verbanden. Om de KL ook in de toekomst te kunnen blijven ondersteunen bij materieel- en beleidsvraagstukken op het gebied van OKE, is een inventarisatie gemaakt van de momenteel beschikbare onderzoeksmethoden en -modellen die ingezet worden om vraagstukken betreffende het optreden en de operationele effectiviteit te beantwoorden. Om na te gaan of de beschikbare modellen en methoden geschikt zijn om domeinspecifieke (Kleine Eenheid) vraagstellingen te kunnen onderzoeken, is de takenlijst uit het project 'Tactisch Optreden kleine eenheden' als uitgangspunt genomen. Er is voor elke specifieke taak gekeken in welke mate de modellen bruikbaar zijn. Door de modellen te kwalificeren op basis van directe toepasbaarheid zijn drie categorieën ontstaan, namelijk praktisch toepasbaar (alle onderliggende relaties zijn bekend), theoretisch mogelijk (er wordt een causaal verband verondersteld tussen twee of meerdere grootheden maar de relaties zijn nog niet of nauwelijks gekwantificeerd) en logisch mogelijk (er is een verband mogelijk tussen twee gemeten grootheden maar het is nog niet duidelijk hoe dat verband ligt). Aan de hand van een matrix van taken x methoden is nagegaan in hoeverre de bij TNO beschikbare methoden/modellen gekwalificeerd zijn om uitspraken te doen over de resultaten van taken.
Bij analyse van de gegevens blijkt dat geen enkel methode uitspraken doet over alle taken van de kleine eenheid. Bovendien valt op dat TNO weliswaar beschikt over meerdere modellen die uitspraken doen over specifieke taken , maar deze taken vallen allen in de categorie 'hoger geweldspectrum'. TNO beschikt niet over expliciete modellen en methoden die praktisch toepasbaar zijn op taken die met name vallen in de categorie 'niet gevechtstaken'.
Een klein aantal methoden en modellen die bruikbaar zijn gebleken voor de gevechtstaken hebben ook het potentieel om te worden toegepast voor niet-gevechtstaken.

Summary

One of the primary goals of the Netherlands Armed Forces is to have at their disposal units that are adequately equipped and outfitted to carry out tasks across the complete range of peace-supporting missions, varying in levels of hostility. To this end a scientific research program was formulated which encompasses a number of projects which focus on various aspects of operations of teams of dismounted soldiers. The aim of this project is to identify scientific methods and models which facilitate the measurement of operational effectiveness of dismounted small units.
Measuring operational effectiveness of dismounted small units requires the use of methods models and simulations. Within this project we have made an inventory of the available methods and models within the TNO technology portfolio. In order to be able to asses the usefulness of these methods and models for the tasks the dismounted small units are confronted with, the task decomposition developed in the project Small unit tactics in peace keeping operations' (Smeenk et al., 2004) was used as a guideline. The usefulness of the methods and models was established by classifying these into three categories, i.e. logically possible, theoretically feasible and practically applicable. For each of the tasks the models and methods were reviewed with respect to the mentioned categories. This resulted in one matrix of tasks and models/methods.
The analysis of the matrix suggests that not one single method/model is practically applicable to all the identified tasks of the dismounted small unit. Furthermore, although TNO has access to a range of models/methods which are practically applicable to a number of tasks, these tasks can al be considered as high intensity tasks. TNO does not have access to methods/models which are explicitly and practical applicable in the low intensity range of the task spectrum.
A small number of models seem to have the potential to fill the identified gap.

Contents

1 Introduction

One of the primary goals of the Netherlands Armed Forces is to have at their disposal units that are adequately equipped and outfitted to carry out tasks across the complete range of peace-supporting missions, varying in levels of hostility. Key to this task execution is that the results of the operations should be discernibly effective and appropriate. In the execution of peace-supporting operations, the emphasis is on operating in smaller groups. This form of operating, under often difficult circumstances, in complex terrain and with a whole range of new threats, makes new demands on the composition of such units and the kit with which they are outfitted.
The defence research program entitled Small Unit Operations generates knowledge, both theoretical and applicable, and infrastructure in order to quantify and qualify the operational effectiveness (OE) of small units during various types of peace-supporting operations. The generated knowledge and infrastructure will provide TNO with the tools needed to respond more adequately and more efficiently to future questions regarding small units.
In the generation of the knowledge needed to respond to operational questions regarding small units, two issues are of foremost importance: 1) the factors indicative of the performance of small units (think of outfitting, unit composition, and situational factors) and 2) methods to measure or assess the value of the various factors. Once the factors are specified and the value is known, it is possible to model the performance of small units and, from there, to acquire predictive insight into how changes in the identified factors affect a unit's performance.
The present study aims first to identify methods available to TNO and the Netherlands Armed Forces with which to measure or assess the operational effectiveness of small units, and the factors that determine OE. Once this has been achieved, the second aim of this study is to take the first step toward the identification of the determinants of OE for small units. That is, which factors determine the OE of a small unit and how do the factors relate to each other?
This report is an account of the activities carried out in order to reach the desired project goals. In Chapter 2 we examine various general premises upon which the work was based. We offer a conceptual model and define various key concepts. In Chapter 3 we make an inventory and evaluation of the empirical methods available with which to measure and assess OE and its determinants. In Chapter 4 we inventory various models and simulations relevant for assessing the OE of small units. In Chapter 5 we make first tentative step towards identifying the contents of a model representing the determinants of OE for small units. Chapter 5 recaps the main conclusions from the study.

2 Methods

2.1 Operational effectiveness

Measuring Operational Effectiveness of small dismounted units: Methods and Models
Before presenting the results of the inventory of research methods and models that can be used to measure or assess the operational effectiveness of an operation of a small unit, we need to first define operational effectiveness and how it can be estimated. In the project Measures of effectiveness for the RNLA (2002) in the small unit operations research program, OE was described as the end result of the task execution of a small unit with a particular make up and kit in a particular environment. OE describes the degree to which the achieved effects match the desired effects. Essential to an accurate assessment of operational effectiveness is a specific definition of what the desired effects or state are. In Effects and Values, we described in considerable detail that it is necessary to define *realization criteria*, which must be met in order to conclude that an operation was effective. Because in peace-supporting missions the achievement of goals is not always dichotomous, the realization criteria are ideally not discrete values, but are based on continua, which can take on a whole range of values. Using these values, it is possible to specify when the desired effects have been completely achieved, achieved to a satisfactory level, and when the levels are still unsatisfactory.
In the present study, we examined ways to assess the levels of key variables and integrate these assessments in order to draw conclusions regarding the OE. This conceptual process is illustrated in Figure 1 and is as follows. Operational effectiveness, preferably as a single value, is a combined measure based on the different variables that can affect the performance of a small unit. These variables can be, for example, characteristics of the small unit itself (composition, size, physical state), the environment in which the unit must operate (climate, landscape, culture), or organizational constraints (orders, infrastructure, kit). In order to calculate the OE based on the relevant variables, models can be developed mathematically in which the variables are specified as well as how the variables relate to each other. Though it is possible to theoretically identify variables that determine OE, in order to calculate the operational effectiveness itself, it is necessary to assign values to the variables. These input values, however, do not appear out of thin air, but must be measured empirically. In some cases this is as simple as measuring the temperature with a thermometer. In cases, however, in which the variables are related to more behavioural aspects of an operation (e.g., winning the hearts and minds of a local population), this is not so simple, and more complex data collection methods are called for.

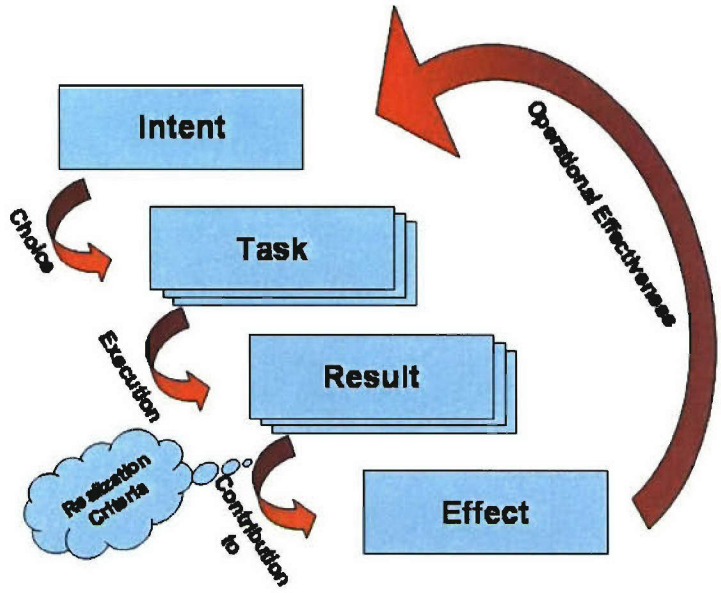


Figure 1 Effect Based Operations – framework.

In practice, Figure 1 is useful when trying to estimate the effects of a particular aspect of a future mission. For example, using the above model, we can gain a better understanding of the effects of a particular piece of kit on the operational effectiveness. We can measure what the effect of the kit is on, say, the situational awareness, and then calculate mathematically what the effects of the resulting change in situational awareness are on the total operational effectiveness.
The other side of the measurement of operational awareness is the evaluation of the effectiveness of an operation that has actually taken place. For example, one may want to know the effects of the activities carried out by a small unit to help rebuild the infrastructure of a village. In this case, the process described above does not suffice. Instead, the link between the OE and empirical data is more direct and is represented in Figure 2. On the left, we see the realization criteria that must be met in order to conclude that an operation was completely, partially or not at all effective. In order to ascertain the degree to which the criteria are met, empirical methods of data collection can be used. The results of these empirical measurements are then compared to the realization criteria. The discrepancy between the measured values and the desired values of the different variables can be integrated in order to draw conclusions regarding the resulting operational effectiveness.

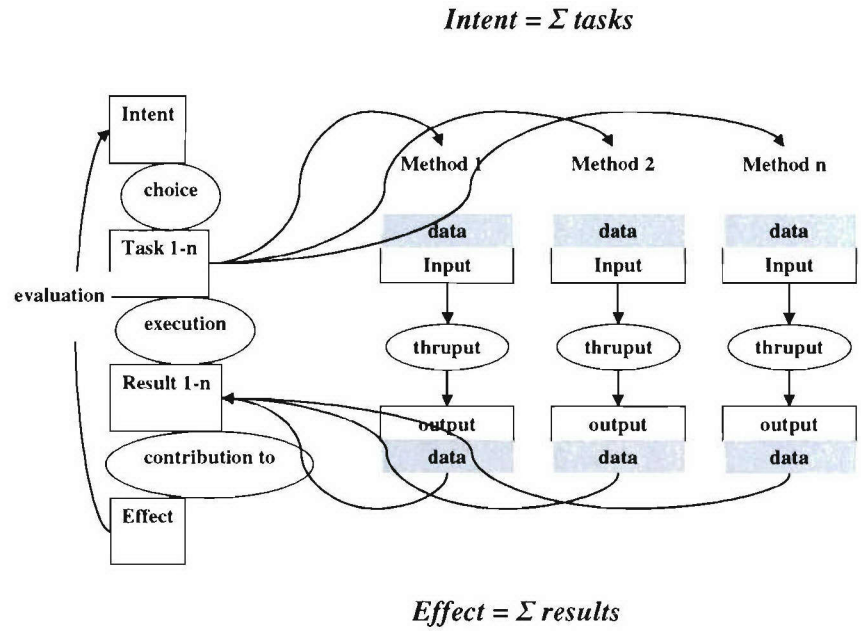


Figure 2 Effect Based Operations and models.

Though conceptually, the process of assessing the operational effectiveness of a small unit operation, there are important aspects of measurement and pre-estimation that determine the quality of the evaluation and its applicability.

2.2 Procedure

In order to give an overview of the methods TNO possesses to determine operational effectiveness, a list of tasks, their objectives and results was abstracted from the project 'small unit tactics in peace keeping operations' (Smeenk et al., 2004). These tasks were used as the basis for this project and summarized in Table 1. The translation of the tasks, their goals and results can be found in Appendix A. The usefulness of all available research and data collection methods available at TNO Defence, Safety and Security, was determined and categorized. Categorization was done based on the maturity and applicability of a specific method in combination with the selected task within TNO Defence Safety and Security. Three categories were distinguished; Logical, Theoretical, and Practical. The description and criteria for these three categories are listed below.

Table 1 Tasks extracted from 'Small unit tactics in peace keeping operations' (Smeenk et al., 2004).

Peace-keeping tasks	Combat Tasks
Construct observation posts	Combat patrol
Man observation posts	Take a position
Conduct patrol	Conduct a fire raid
Security patrol	Conduct a mounted attack
Contact-patrol	Conduct a counter attack
Patrol to locate mines and explosives	Conduct a counter strike
Social Patrol	Establish reinforcements
Inspect vehicles and persons/man checkpoints	Establish a fire base
Inspect sites, areas and buildings	Establish a team collection area
Cordon and search sites, areas and buildings	Perform a tactical movement
Monitor/protect objects, areas and persons	Perform an infiltration or exfiltration
Escort/convoy security and protection	Conduct an attack on foot or a dismounted attack
Quick reaction force	Conduct an advance
Weapon collection activities	
Conduct liaison	
Showing the force/flag (e.g. shooting exercises)	
Spreading of Info Ops products (e.g. flyers)	
Inform civilians and local organisations about mine awareness	
Reconnaissance with other means than patrols (RPV, EOV, Radar, etc.)	
Provide assistance in rebuilding the local infrastructure	
Supply class I, II, III, IV, V	
Re-establishing communications	
Transport support (drivers, vehicles)	
Support to crowd and Riot Control (CRC) operations	
Support to arrests (security and protection)	
Transport support (drivers, vehicles)	

2.2.1 *Logical*

At the highest abstraction level, methods can be identified which are plausible and could be executed but would require extensive research in identifying the relevant factors and their causal relationships. Furthermore parameters and weights will not be readily available and would require extensive empirical research.

2.2.2 *Theoretical*

Less abstract than *logical* methods, theoretically feasible methods do not require the identification of factors and their causal relationships. Models and methods which are best described by this qualification are relevant and have been tested but do not include the domain specific parameters and weights. These models, to be applicable, still require considerable empirical testing and the gathering of domain specific parameters and weights.

2.2.3 *Practical*

Models and methods which are best qualified as being practical have been empirically tested but also in the relevant domain. These models and methods can be applied without much extra effort.

Common scientific research methods and data collection methods include experiments, field studies, archival research, interviews, observations, surveys and the analysis of pre-existing data. These methods are described in great detail in Appendix 0.

These methods are being used to gather input (data) for models as explained in Figure 2. The 'throughput' consists of a scheme of comparisons and formulae (model) that describe the relationship between empirically obtained measures (input) and the result for a specific operational context (output).

The models that can be used to understand and describe the relationship between input and output are described in great detail in Appendix 0. These models were reviewed for the tasks, their objectives and results from 'small unit tactics in peace keeping operations' (Smeenk 2004) and categorized as logical, theoretical or practical. The complete matrix can be found in Appendix 0.

3 Empirical methods

The key to answering any research question is to choose the right method with which to find the answer. Just as you would not use a thesaurus to find a recipe for Beef Wellington, you should not use an experiment to study a phenomenon that would be better suited to research using interviews. In this chapter we inventory various methods with which empirical data can be collected that can later be used as input for a more integrative model or simulation with which complex concepts such as operational effectiveness can be measured or assessed.

3.1 Longitudinal and cross-sectional research

In conducting research it is often desirable to determine causality. That is to say, to be able to conclude that one variable or process *causes* another. This is often very difficult, particularly with social or behavioural phenomena. Other times it is desirable to contrast and compare two or more situations in order to determine which is better or more effective. In order to aid in these processes of the determination of causality and multiple comparisons, there are two main ways in which a study can be designed and administered: longitudinal and cross sectional.

3.1.1 Longitudinal designs

Longitudinal refers to research in which a particular measure is administered repeatedly over time. Census studies are examples of longitudinal designs: censuses may be taken once every so many years in order to determine the make-up of the population on a variety of dimensions such as age, occupations, household composition, etc. Using a longitudinal design also allows causality to be determined. The dimensions of interest are measured in order to establish a baseline (t_0; the number of firearms turned into occupying forces over a period of, for example, a week), a manipulation of the relevant variable is introduced (a PsyOps money-for-firearms campaign) and the dimension of interest is measured a second time (t_1; the number of firearms turned in during the first week of the campaign). By comparing t_0 and t_1, we can determine the increase in the number of firearms turned in as a direct result of the PsyOps campaign (the PsyOps campaign 'causes' people to turn in their weapons).

We can also use longitudinal designs to compare multiple situations. These types of designs are usually referred to as *repeated measures*. For example, if we want to test soldiers' ability to navigate using traditional locating and navigational devices versus using Soldier Digital Assistants (SDA), we may ask a group of soldiers to perform navigational task first using traditional equipment and then a second time using SDA's.

The main drawback of using longitudinal designs is that it is difficult to determine if the results that are found are due to the interventions or due to the passage of time. For example, how do we know that people wouldn't have started turning in more firearms anyway, even without the introduction of the PsyOps campaign? Maybe there was something else that happened that encourage people to start turning in their weapons, for example, a revered civic leader made a statement that he was in favour of the disarming of civilians. To tease apart the effects of our intervention from other effects in the environment, we need a different type of design: the cross-sectional design.

3.1.2 Cross-sectional designs

Cross-sectional designs compare two groups who are similar on a number of relevant variables, using a measure administered at one moment in time. This is the classic design using control groups. For example, we want to know the effect of a particular medication on relieving symptoms of the common cold. To test this we can give one group of people with a cold the medication (treatment group) and the other groups nothing (or, better yet, a placebo; control group). To test the effectiveness of the medication, we can ask the participants to tell us how they fell on a number of cold-related dimensions (sneezing, stuffy nose, headache, sore throat, coughing). If the treatment group indicates significantly fewer symptoms than the control group, we can conclude that the medication 'caused' people to feel better.

It is possible to combine cross-sectional designs with longitudinal designs in order to gain more insight in to the phenomenon of interest. To continue with the example of the money-for-firearms campaign: we choose two comparable villages. Over a period of a week we count the number of firearms that villagers spontaneously turn over to the occupying forces. We subsequently start a money-for-firearms campaign in one of the villages, but not in the other (An additional option would be to compare a money-for-firearms campaign with a campaign encouraging villagers to turn in firearms without the promise of a reward). We measure the number of firearms turned in both villages in the first week of the campaign. In principle, we hope for the following pattern of results: in the first measurement week the inhabitants of both villages turn in equal numbers of firearms; in the second measurement week inhabitants of the village that has the money-for-firearms campaign turn in more weapons than the inhabitants of the control village. Assuming that people from elsewhere did not turn in their firearms in the treatment village, we can conclude that the money-for-firearms campaign 'caused' people to turn in their firearms.

Alternatively, if we find that in the second measurement week equal numbers of firearms were turned in both villages, we have reason to believe that something else is going on. If, in the second measurement week both villages differ from the baseline measure, but not from each other, we can conclude that there was some other factor that occurred between the first and second measurement weeks that is responsible for the increase. On the other hand, if neither village shows a change between the two measurement weeks, we can conclude that the PsyOps campaign was not effective.

3.2 Reliability

The reliability of a measurement refers to the accuracy of the measure used. Reliability is usually assessed by measuring the same object or dimension more than once (using either the same or a similar instrument). If the two measurement moments yield results identical within a specified margin of error (determined by correlating the different scores), the measure is considered to be reliable. For example, the Stanford-Binet IQ-test has a standard error of 3 points. This means that if Person X takes the test on Monday and then again on Friday, his two IQ-scores can differ by plus or minus 3 points. This test is considered reliable because it accurately measures something we define as IQ; that is, multiple test administrations yield similar IQ-scores (whether what the test measure is really IQ or not is a question of validity, not reliability, and will be addressed in the next section). An IQ-test with a standard error of, say, 25 points would be less accurate and therefore less reliable.

3.3 Validity

Validity in measurement is that the method used actually measures what it is supposed to measure. Though this would seem to speak for itself, validity is not always easy to achieve. Let's say we wanted to know the effect of a small unit's help at repairing a school on the local population's attitude toward the occupying force. To find out we could ask the locals how happy they are with the school. The assumption here is that if the small unit does something that makes the locals happy, their attitudes will become more positive towards the occupying forces. However, this question may or may not be a valid measure of the locals' attitudes on this dimension: locals may be very happy that their school has been repaired, but they may still resent the foreign presence in their village.

Validity is difficult to determine because the only true way to evaluate validity is to compare a particular measure to one that is know to be valid. Direct measures often have more validity than indirect ones because it is easier to rule out alternative explanations. We could, for example, ask locals if they approve of the presence of the occupying forces in their village. This question is a more direct measure of what we want to know. The validity is therefore likely to be higher than the school question. To find out the validity of the school question, we could correlate locals' responses to the two questions. If the correlation is positive and high, the school question is valid. We could also correlate the direct question with other measures: attacks on foreign soldiers, threats or insults shouted towards foreign soldiers etc. If the correlation is negative and high, we can conclude that all are valid measures of the locals' attitudes towards the occupying forces.

The validity of a measure also depends on the construct being measured. Measuring the length of a house is easy because the construct 'length' is relatively straightforward in this case. In the section on reliability we gave the example of IQ. IQ is difficult to measure in a valid manner because the construct 'IQ' is very complex and there is much disagreement on what makes a person intelligent. For this reason, it is difficult to determine the validity of IQ-tests.

In general terms, we can distinguish between two important types of validity:

Internal validity which is the degree to which differences in performance can be attributed unambiguously to an effect of an independent variable, as opposed to an effect of another (uncontrolled) variable; an internally valid study is free of confounders.

External validity which is the extent to which the results of a research study can be generalized to different populations, settings and conditions.

3.4 Shelf life

Once data have been collected on a particular topic of study, they can be brought in connection with other data in a model or generalized to other situations. However, the validity of extrapolating the meaning of data through such activities is not always the same: data have a shelf life. The circumstance in which data are collected can result in the data only being meaningful *in those circumstances*.

Consider measuring the boiling point of water a sea level. Water boils at 100 °C at sea level. However, this measurement does not generalize to other altitudes: the boiling point of water is negatively correlated with altitude, that is, the higher you are, the lower the temperature at which water boils. Consequently, if you apply the measurements taken at sea level to a situation occurring at a higher altitude, your

extrapolation will yield incorrect results. In another example, the results of studies of socially correct behaviour in Afghanistan are not automatically applicable in Iraq. In sum, data have a shelf life in terms of space.
Data also have a shelf life in terms of time. Though the chances are good that water at sea level will always boil at 100 °C, measurements of more behavioural or cultural variables will change over time. Cultural norms change, people's attitudes change, and available resources change. As a result, measuring people's attitudes towards occupying forces today does not necessarily predict their attitudes a year from now. Consider the change in Europeans' attitudes towards the United States in the past five years.

4 Data

4.1 The matrix

As explained in Chapter 2.2, tasks were abstracted from 'small unit tactics in peace keeping operations' (Smeenk et al., 2004). The tasks were placed in a matrix, together with the available models, as shown in Table 3. The available models are summarized in Table 2 (Jaiswa 1997).

Table 2 Available models and their usability.

Model	Description (usability of methods)
Search and damage assessment	Search models can increase the situation awareness or can give information about the position of an enemy. The output of damage assessment is the probability or the proportion of the area of a target damaged by a weapon or weapons. So these methods can be used for every task where the yield is to give information about the environment, the enemy or the consequences of firing a weapon.
Simulation of military systems	The yields of all tasks can be analysed with simulation. Simulation is like representing the truth in a model, so everything in reality can be analysed through simulation.
War games	War games are simulations of a military operation involving two or more opposing forces. War games can be used where information is needed for training capabilities, the effectiveness of a procedure or plan or doctrines or weapon systems.
Homogeneous and heterogeneous combat models	Homogeneous models are based on attrition warfare. The output of these models is which party will probably win the conflict. So these models can be used when information has to be given about the effectiveness of a combat, such as the amount of enemy casualties.
Cost effectiveness analysis	This method gives information about the best system to be chosen given the assumptions concerning effectiveness and costs. So this method will only be used when systems have to be compared on cost and effectiveness aspects.
Multiple Criteria Analysis	MCA will be used when there has to be made a choice. Questions which can be answered are for example how to protect the own troupes to get the least victims or how to collect weapons to inn the most.
Analytic optimization models	These models can be used for almost every task, because almost every task can be optimised. Only the tasks which are exactly described by standard procedures are excluded.
Heuristic optimization models	These models can be used for almost every task, because almost every task can be optimised. Only the tasks which are exactly described by standard procedures are excluded.
Drama theory	Drama theory addresses problems involving multiple parties with conflicting objectives. This is a variant of game theory. Drama theory also takes into account the way people play games at different levels at the same time. So for every task where war games can be used, drama theory can be used too. They can also be used where information is needed about emotional aspects.
Quantitative threat assessment: static and dynamic analyses	These techniques give information about the threat of the opponent. So when information is needed about the enemy or safety, threat assessment can be used.
Belief networks and influence diagrams	These networks analyse the relationships between different elements. So these can give information about relations or influences between people or actions.

Table 3 Schematic overview of the construction of the matrix.

	Model 1	Model 2	....	Model i
Task 1				
Task 2				
....				
Task i				

The qualifications Logical (L), Theoretical (T) and Practical (P) were filled in the cells for each combination of model*task. The complete matrix can be found in Appendix B.
The analysis of the matrix was done per model (vertical analysis) and per task (horizontal analysis). The vertical analysis shows applicability of the models in general and gives an indication of the feasibility of a specific model in this context. The horizontal analysis shows the availability of models to solve task-specific research questions. In other words, it shows if (and how many) models are practically available for a certain task.

4.1.1 Blanks

40% of all cells in the matrix were left blank. These blank cells in the matrix represent combinations of tasks and models that could not be categorized. A categorization for these methods for the specific task does not seem relevant at all. For example, 'war games' do not seem to be a relevant method to determine the result or (contribution to) the effect of an information task (for example informing civilians on mines). The total amount of (non)blank cells for a specific model gives insight in the applicability of these models for small unit operations research.

4.1.2 Logical

For 33% of all possible combinations, models were categorized to be logical (the highest abstraction level).

4.1.3 Theoretical

For 55% of all combinations, theoretical feasible methods are available. The expertise of the method and relevance within the domain are recognized. However, the domain specific parameters and weights are not available (yet).

4.1.4 Practical

The inventory of models shows that in 12% of all possible combinations (models X task) models that are tested and relevant within the domain are available.

4.2 The Models

When performing the vertical analysis, we can roughly consider three clusters based on the amount of blanks, L's, T's, P's. The models that score a lot of blank cells or L's (logical), seem little promising in solving task specific research questions for small unit operation research. This cluster consists of 'homogeneous and heterogeneous combat models', 'cost effectiveness analysis', 'multiple criteria analysis', 'drama theory' and 'quantitative threat assessment' models (modelling techniques) 'analytic optimization', 'heuristic optimization' 'belief networks and influence diagrams' are models (modelling techniques) that score a relatively large amount of T's (Theoretical), which means that they show a lot of potential to be applied in solving task specific research questions. However, before the models can effectively been used, a considerable amount of empirical testing and gathering of domain specific parameters and weights has to be done.
Based on the total amount of P's, (Practical) the 'search and damage assessment', 'simulation of military systems' and 'war game' models can be qualified as most promising. For these models there is knowledge and experience available at TNO and the models can directly be applied to solve research questions.
The models and their qualifications are summarized in Table 4.

Table 4 Models and their qualifications.

Little promising	Lot of potential	Promising
Homogeneous and heterogeneous combat models	Analytic optimization	Search and damage assessment
Cost effectiveness analysis	Heuristic optimization	Simulation of military systems
Multiple Criteria Analysis	Belief networks and influence diagrams	War games
Drama theory		
Quantitative threat assessment: static and dynamic analyses		

4.3 Tasks

When considering the application from a task point of view, the qualification of the models shows the amount of knowledge and expertise for specific tasks.
If practical applicable models per task are available, means that empirically tested knowledge is available for this task. Logically, it is desirable to have at least one method that is categorized 'practically' for each task.
When the amount of P's is more than one for a specific task, that the performance measurement for this specific task has yet been studied from more than one perspective (e.g. by the use of more than one model). The methods have been empirically tested in the relevant domain. Hence, the use of more than one relevant model increases the validity of the prediction of eventual task performance (result).
Analyzing the qualification of tasks in the matrix, shows that the largest amount of P's can was found for combatant tasks. For non-combatant tasks, there is hardly any empirically tested data available.

5 Discussion and conclusions (synthesis)

The results of all tasks a mission comprises of have to be evaluated and quantified in order to make Operational Effectiveness measurable (Figure 2). There are several models available to quantify the results of a task as discussed in the chapters before. To evaluate operational effectiveness of a mission, at least one model should be able to quantify the result of all tasks involved in that mission.
The inventory of models, in combination with tasks, performed in this study shows that no there is no model available that can practically or be used to quantify all tasks for small unit operations. The most promising models to do so in future are the models that only score P's or T's in the inventory, like 'simulation of military systems' and 'influence diagrams and belief networks'.
Another remarkable result of the inventory is that the expertise and knowledge of TNO is available for combatant tasks. For several tasks, like 'conduct an attack' or 'perform a tactical movement' data and numbers are available and 4 different types of models can directly be applied to answer research questions (4 P's and 5 T's).
Based on the matrix we can conclude that, in general, that there is a lack of knowledge and expertise on non-combatant tasks at TNO. It is probably also true that this gap is a world-wide issue. The relations between variables are not known for the majority of these tasks. In OKE inclusive this project we make an attempt to get a first grasp on defining the gap and start closing it.

6 References

De Jong, K.Y., Voskuilen, M.J.M., Van Elst, N.P. & Barbier, R.R. *Measures of effectiveness of the RNLA* (2003) (TNO rapport FEL-02-I318).

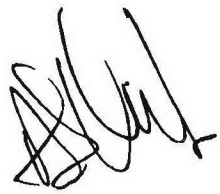
Jaiswal, N.K. - *Military Operations Research, quantitative decision making*, Kluwer Academic Publishers, Boston/Dordrecht/London, 1997.

Smeenk, B.J.E., Barbier, R.R., Wilschut, J.A., Fiamingo, C. & Knijnenburg, S.G. (2004). *Tactisch optreden van kleine eenheden in vredesoperaties.* (TNO rapport FEL-03-A288).

7 Signature

Soesterberg, July 2006

TNO Defence, Security and Safety



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A Dutch-English Translation of Tasks

Taak	Task	Doel	Goal	Resultaat	Result
Inrichten waarnemingspost	Construct observation posts	Verbindingen leggen; Slaapplaatsen creeeren; Inrichten post	Establish connections, create sleeping accommodation, arrange post	Complete waarnemingspost ingericht	Arrangement observation post completed
Bemannen waarnemingspost	Man observation posts	Waarnemen terrein en opponent en doorgeven info	Observe terrain and opponent; communicate intel	Inlichtingen over terrein en opponent gewonnen	Gathered intel on terrain and opponent
Verkennings-patrouille	Reconnaissance patrol	Waarnemen terrein en opponent en doorgeven info	Observe terrain and opponent; communicate intel	Inlichtingen over terrein en opponent gewonnen	Gathered intel on terrain and opponent
Gevechtspatrouille	Combat Patrol	Uitschakelen dreiging	Neutralize threat	Vijandelijke eenheden uitgeschakeld	Hostile forces are neutralized
Beveiligings-patrouille	Security Patrol	Penetratie vijand voorkomen; Beveiliging eigen terreindelen	Prevent the enemy to access own area; secure own terrain	Vijandelijke penetratie eigen gebied voorkomen; Veiligheid vergroot	Access of hostile troops prevented; increase of security
Contactpatrouille	Contact- Patrol	Verbinding tussen twee eenheden	Connection between two units	Informatie uitgewisseld tussen eenheden	Information exchange between units
Mijn- en explosief opsporings-patrouille	Patrol to locate mines and explosives	Mijnen/explosieven vinden	Find mines/-explosives	In kaart gebracht mijnenveld; Gecontroleerde veilige gebied	Map minefield; checked secure area
Sociale patrouille	Social Patrol	Contact met bevolking	Communication with local population	Inlichtingen uit bevolking gewonnen; Vertrouwen gewonnen; Openheid bevolking is vergroot; Toegankelijkheid bevolking is vergroot	Obtain intelligence form local population; gained trust; openness of population is increased; accessibility of population is increased.
Inspecteren van voertuigen en mensen (checkpoints)	Inspect vehicles and persons/man checkpoints	Op de hoogte blijven verplaatsing	Stay informed of movements	Ongecontroleerde verplaatsing voorkomen	Prevent uncontrolled movements

Taak	Task	Doel	Goal	Resultaat	Result
Inspecteren van gebieden en gebouwen (site inspectie)	Inspect sites, areas and buildings	Controleren wapen en munitievoorraden	Monitor weapon and ammunition storage	Niet ingezette wapens	Non-used weapons
Afsluiten en doorzoeken van gebouwen en gebieden	Cordon and search sites, areas and buildings	Personen en explosieven zoeken; innemen van gebouw	Search persons and explosives; take building	Personen en explosieven gevonden; gebouw/gebied ingenomen	Found persons and explosives; take building
Beschermen en beveiligen van objecten, gebieden en personen	Monitor/protect objects, areas and persons	Verzamelen, doorgeven gegevens en penetratie van vijand voorkomen	Collect and pass information in order to prevent enemy access	Vijandelijke penetratie eigen gebied voorkomen	Prevented hostile access of own area
Escorteren, konvooi beveiliging/ bewaking	Escort/convoy security and protection	Beveiligen verplaatsende eenheid	Secure moving units	Veilig getransporteerde goederen/person en	Secured transportation of persons/goods
Quick reaction force	Quick reaction force	Ondersteunen eenheid	Support unit	Verhoogde operationele inzetbaarheid eenheid	Increased operationality of unit
Wapeninzamel-acties	Weapon collection activities	Voorkomen inzet wapens	Prevent (hostile) use of weapons	Wapens ingezameld en verhoogde veiligheid	Weapons collected and increased security
Liaison uitbrengen (bemiddelen)	Conduct liaison	Uitwisselen informatie	Exchange information	Verbeterde coordinatie tussen alle partijen	Improved coordination between parties
Showing the force/flag (voorbeeld schietoefeningen)	Showing the force/flag (e.g. shooting exercises)	Sterkte tonen	Show own capabilities/ strength	Geïntimideerde vijand en verhoogd gevoel van veiligheid onder de bevolking	Enemy intimidated, sense of safety among population is increased
Verspreiden van Info Ops producten (posters, folders etc.)	Spreading of Info Ops products (e.g. flyers)	Voorlichten bevolking	Inform population	Vergroten veiligheidsgevoel bij bevolking	Increase sense of safety among population
Voorlichten van burgers en lokale organisaties in mine awareness	Inform cilvilians and local organisations about mine awareness	Voorlichten bevolking over mijnen	Inform population on mines (mine-awareness)	Voorkomen mijnongevallen, goodwill kweken bij bevolking	Prevent mine-accidents, create goodwill among population

Taak	Task	Doel	Goal	Resultaat	Result
Verkenning met andere middelen dan patrouilles (RPV, EOV, radar etc.)	Reconnaissance with other means than patrols (RPV, EOV, Radar, etc.)	Waarnemen terrein, info doorgeven	Observe terrain, pass/exchange information	Inlichtingen over terrein en opponent gewonnen	Gathered information on terrain and opponent
Ondersteuning leveren bij het herstellen van de lokale infrastructuur	Provide assistance in rebuilding the local infrastructure	Infrastructuur verbeteren	Improve infrastructure	Infrastructuur verbeterd; Woon en leef klimaat verbeterd	Improved Infrastructuur; Living conditions are improved
Aanvoer van klasse I, II, III, IV, V	Supply class I, II, III, IV, V	Goederen transporteren	Transport goods	Voorraden bijgevuld	Replenished stocks
Instellen van verbindingen	(Re-)establishing communications	Communicatie tussen eenheden	Communication between units	Eenvoudige informatie uitwisseling	Information exchange
Leveren van transportsteun (voertuigen, chauffeurs)	Transport support (drivers, vehicles)	Transportcapacteit vergroten	Increase the capacity of transport	Meer goederen/ eenheden getransporteerd	Increase in transportation of goods/units
Ondersteuning leveren voor Crowd and Riot Control (CRC) operatie	Support to Crowd and Riot Control (CRC) operations	Escalatie bevolkingsopstand voorkomen	Prevent riotering of population	Gecontroleerde bevolking	Population under control
Ondersteuning leveren bij arrestatie (bewaking en bescherming)	Support to arrests (security and protection)	Escalatie tijdens arrestatie voorkomen	Inhibit escalation of aggression during arrest	Gecontroleerde arrestatie	Controlled arrest
Coördinatie met aangrenzende eenheden	Transport support (drivers, vehicles)	Verbinding tussen twee eenheden onderhouden	Maintain connection between units	Informatie uitgewisseld verbeterde taakuitvoering	Information exchange; improved task performance
Innemen van een opstelling	Take a position	Verdedigen terreindeel door middel van uitbrengen vuur	Defend terrain by firing	Gebied behouden, overgenomen initiatief	Kept own area, took over initiative
Uitvoeren van een vuuroverval	Conduct a fire raid	Uitschakelen vijandelijke eenheden	Neutralize hostile units	Vijandelijke eenheden uitgeschakeld	Hostile units neutralized
Uitvoeren van een aanval (bereden)	Conduct a mounted attack	Gebied veroveren; zuiveren gebied (uitschakelen vijandelijke eenheden)	Claim area; clear area (neutralize hostile units)	Gebied veroverd, vijandelijke eenheden uitgeschakeld)	Area taken, hostile units neutralized

Taak	Task	Doel	Goal	Resultaat	Result
Uitvoeren van een tegenaanval	Conduct a counter attack	Hernemen gebied; uitschakelen vijandelijke eenheden	Reclaim area, neutralize hostile units	Gebied heroverd; vijandelijke eenheden uitgeschakeld	Area taken, hostile units neutralized
Uitvoeren van een tegenstoot	Conduct a counter strike	Uitschakelen vijandelijke eenheden, Vijand tijdelijk initiatief ontnemen	Neutralize hostile units, take over initiative	Vijandelijke eenheden uitgeschakeld, Tijd en initiatief gewonnen	Hostiles neutralized, regain initiative
Uitvoeren van een versterking	Increase fighting strength	Gevechtskracht vergroten	Increase fighting strength	Gevechtskracht vergroten	Fighting strength increased
Uitvoeren van een vuurbasis	Establish a fire base	Ondersteunen manouvre eenheid, suppressie van vijandelijke eenheden	Support units maneuvers, suppress hostile units	Gesuppresseerde vijandelijke eenheden	Hostile units kept under suppression
Innemen van een teamverzamel-gebied	establish a team collection area	Verzamelen eenheden	Assemble units	Gehergroepeerde eenheden	Assembled units
Uitvoeren van een tactische verplaatsing	Perform a tactical movement	Verplaatsen door terrein, uitschakelen vijandelijke eenheden	Move through terrain, neutralize hostile units	Eenheid verplaatst, vijandelijke eenheden uitgeschakeld	Unit moved, hostile units neutralized
Uitvoeren van een infiltratie of exfiltratie	Perform an infiltration or exfiltration	Onopgemerkte verplaatsing door vijandelijk gebied; contact met eigen eenheden maken	Unnoticed movement through hostile area, contact with own units	Eenheid verplaatst; gegevens terrein en vijand; gebied bezet; vijand misleid; eenheid teruggekeerd in eigen gebied	Unit moved, information terrain and enemy, area taken, misled enemy, unit returned to own area
Uitvoeren van een aanval te voet of een uitgestegen aanval	Conduct an attack on foot or a dismounted attack	Gebied veroveren; zuiveren gebied (uitschakelen vijandelijke eenheden)	Conquer area; clear area (neutralize hostile units)	Gebied veroverd, vijandelijke eenheden uitgeschakeld	Area taken, hostile units neutralized
Uitvoeren van een opmars te voet	Conduct an advance	Verplaatsen door terrein	Move through terrain	Eenheid verplaatst	Unit moved

B Data matrix tasks*methods

nr	Task	Goal	Result	Search and damage assessment	Simulation of military systems	War games	Homogeneous and heterogeneous combat models	Cost effectiveness analysis	Multiple Criteria Analysis	Analytic optimization models	Heuristic optimization models	Drama theory	Quantitative threat assessment: static and dynamic analyses	Belief networks and influence diagrams	P	IT	L	Marks
			Intent -> Effect		SDA study	x		x (LCC SMP)	x (vervanging YPR, ...)			x (KL scenario ontwikkeling, SPECTRUM)	x (DRR, ACROSS)	Influence Diagram Dutch Bat				
			Track Record TNO	CAEn IWARS SMARTER SCOPE	FSM SMARTER IWARS	CAEn KIBOWI Scenario development Confrontation Analysis	SCOPE Lanchester ...	FEL-SALDO SUITCASE	TOPSYS Group Systems (GFR)					DPL				
			Usability of the methods	Search models can increase the situation awareness or can give information about the position of an enemy. The output of damage assessment is the lethability or the	The yields of all tasks can be analysed with simulation. Simulation is like representing the truth in a model, so everything in reality can be analysed through simulation.	War games are simulations of a military operation involving two or more opposing forces. War games can be used where information is needed for training capabilities.	Homogeneous models are based on attrition warfare. The output of these models is which party will probably win the conflict. So these models can be used when information has to	This method gives information about the best system to be chosen given the assumptions concerning effectiveness and costs. So this method will only be used when systems have	MCA will be used when there has to be made a choice. Questions which can be answered are for example how to protect the own troupes to get the least victims or how to collect weareons in inn	These models can be used for almost every task, because almost every task can be optimised. Only the tasks which are exactly described by standard procedures are	These models can be used for almost every task, because almost every task can be optimised. Only the tasks which are exactly described by standard procedures are	Drama theory addresses problems involving multiple parties with conflicting objectives. This is a variant of game theory. Drama theory also takes into account the way people play	These techniques give information about the threat of the opponent. So when information is needed about the enemy or safety, threat assessment can be used.	These networks analyse the relationships between different elements. So these can give information about relations or influences between people or actions.				
1	construct observation posts	Establish connections, create sleeping accomodation, arrange post	Arrangement observation post completed		L	L		L	L	T	T	L		IT	0	3	5	3
1.1	Man observation posts	Observe terrain and opponent; communicate intel	Gathered intel on terrain and opponent	T	T	T		L	L	T	T	L		IT	0	6	3	2
2.1	conduct patrol	Observe terrain and opponent; communicate intel	Gathered intel on terrain and opponent	T	L	L		L	L	T	T	L		T	0	4	5	2
2.2	Gewestelijk-patrouille	neutralize threat	Hostile forces are neutralized	P	P	T	T	L	L	T	T	L	L	T	2	5	4	0
2.3	Bevolkingsgo-patrouille	Prevent the enemy to access own area; secure own terrain	access of hostile troops prevented; increase of security	T	T	T	T	L	L	T	T	L	L	T	0	7	4	0
2.4	Contact-patrouille	Connection between two units	Information exchange between units		L	L		L	L	T	T	L		T	0	3	5	3
2.5	Mijn- en explosief opsporings-patrouille	Find mines/ explosives	Map minefield; checked secure area	T	T	T		L	L	T	T	L	L	T	0	6	4	1
2.6	Social Patrol	Communication with local population	Obtain intelligence form local population; gained trust; openness of population is increased; accessibility of population is increased.		L	L				L	L	L		T	0	1	5	5
3	Inspect vehicles and persons/ scan checkpoints	Stay informed of movements	Prevent uncontrolled movements		T	T				T	T	L		T	0	5	1	5
4	Inspect sites, areas and buildings	Monitor weapon and ammunition storage	Non-used weapons		T	T				T	T	L	L	T	0	5	2	4
5	Cordon and search sites, areas and buildings	Search persons and explosives; take building	found persons and explosives; take building	L	T	T				T	T	L		T	0	5	2	4
6	Man/ and protect objects, areas and persons	collect and pass information in order to prevent enemy access	Prevented hostile access of own area		L	L				T	T	L	L	T	0	3	4	4
7	Escort/ convoy security and protection	Secure moving units	secured transportation of persons/ goods	L	T	T				T	T	L		T	0	5	2	4
8	Quick reaction force	support unit	increased operational operationality of unit		T	T				T	T	L		T	0	5	1	5
9	Weapon collection activities	prevent (hostile) use of weapons	Weapons collected and increased security		L	L				T	T	L		T	6	3	3	5
10	Conduct liaison	Exchange information	Improved coordination between parties			L				L	L	L		T	0	1	4	6
11	Showing the force/flag (e.g. shooting exercises)	Show own capabilities/ strength	Enemy intimidated, sense of safety among population is increased		L	L				L	L	L		T	0	1	5	5
12	Spreading of Info Ops products (e.g. flyers)	Inform population	Increase sense of safety among population		L	L				L	L	L		T	0	1	5	5
13	Inform civilians and local organisations about mine awareness	Inform population on mines (mine-awareness)	Prevent mine-accidents. create goodwill among population			L				T	T	L		T	0	3	2	6
14	Reconnaissance with other means than patrols (RPV, EOV, Radar, etc.)	Observe terrain, pass/ exchange information	gathered information on terrain and opponent	T	T	T				T	T	L		T	0	6	1	4
16	Provide assistance in rebuilding the local infrastructure	Improve infrastructure	improved Infrastructuur; Living conditions are improved		L	L				T	T	L		T	0	3	3	5
17	Supply class I, II, III, IV, V	Transport goods	replenished stocks		T	T				L	L	L		T	0	3	3	5

18	Re-establishing communications	Communication between units	information exchange		T	T				L	L	L		T	0	3	3	5
19	Transport support (drivers, vehicls)	Increase the capacity of transport	increase in transportation of goods/ units		T	T		L	L	L	L	L		T	0	3	5	3
20	Support to crowd and Riot Control (CRC) operations	prevent rioteering of population	population under control		L	L				T	T	L		T	0	3	3	5
21	Support to arrests (security and protection)	inhibit escalation of aggression during arrest	controlled arrest		L	L				T	T	L		T	0	3	3	5
23	Transport support (drivers, vehicls)	maintain connection between units	information exchange; improved task performance		L	L				T	T	L		T	0	3	3	5
24	Take a position	defend terrain by firing	kept own area, took over initiative		P	P				T	T		T	T	2	4	0	5
25	Conduct a fire raid	neutralize hostile units	Hostile units neutralized	P	P	P	T			T	T		T	T	3	5	0	3
26	conduct a mounted attack	Claim area; clear area (neutralize hostile units)	Area taken, hostile units neutralized		P	P	T			T	T		T	T	2	5	0	4
27	conduct a counter attack	reclaim area, neutralize hostile units	Area taken, hostile units neutralized	P	P	P	T			T	T		T	T	3	5	0	3
28	conduct a counter strike	neutralize hostile units, take over initiative	Hostiles neutralized, regain initiative	P	P	P	T			T	T		T	T	3	5	0	3
29	Uitvoeren van een versterking	Increase fighting strength	Fighting strength increased		P	P	T			T	T		T	T	2	5	0	4
30	Establish a fire base	Support units manouvre, suppress hostile units	Hostile units kept under suppression		P	P	T			T	T		T	T	2	5	0	4
31	establish a team collection area	collect units	realigned units		P	P				T	T			T	2	3	0	6
32	perform a tactical movement	Move through terrain, neutralize hostile units	Unit moved, hostile units neutralized	P	P	P	T			T	T		T	T	3	5	0	3
33	perform an infiltration or exfiltration	unnoticed movement through hostile area, contact with own units	unit moved, information terrain and enemy, area taken, misled enemy, unit returned to own area	P	P	P				T	T			T	3	3	0	5
34	conduct an attack on foot or a dismounted attack	conquer area; clear area (neutralize hostile units)	area taken, hostile units neutralized	P	P	P	T			T	T	P	T	T	4	5	0	2
35	conduct an advance	move through terrain	Unit moved		P	P				T	T	P		T	3	3	0	5
		waarde																
	0.079254079	P	34	7	13	12	0	0	0	0	0	2	0	0				
	0.354312354	T	152	5	12	13	10	0	0	32	32	0	5	39				
	0.20979021	L	90	2	12	14	0	8	8	7	7	27	5	0				
	0.356643357	blanks	153	25	2	0	29	31	31	0	0	10	25	0				
			429															
	0.123188406	P	34															
	0.550724638	T	152															
	0.326086957	L	90															
	1		276															

C Research methods, models & simulations

Research methods

Experiments

Description
Variables are qualities a researcher wants to study and draw conclusions about. If one wants to determine how two variables relate to each other or how one variable influences another (causal relationship), the most appropriate research method is often an experiment. Experiments are not only extremely suitable to determining causal relationships, but can also be used for the comparison of two (or more) different treatments, concepts or strategies. Experiments can be divided into two types: random or true experiments, and quasi experiments.
Performing an experiment can be described as 'a controlled method of observation in which the value of one or more independent variables is manipulated in order to determine causal effects on one or more dependent variables' (Zechmeister et al., 2001). Experimentation does not so much refer to a specific location or room in which a study is performed, but rather to the rules and assumptions that apply to the set-up of a true experimental design. Within experimental research, the researcher creates an artificial situation in order to ascertain that the effects found are due to the manipulations and not to other (confounding) factors. The researcher controls *who* participates in the experiment, *what* happens during the experiment and the *circumstances* under which the experiment takes place.

Variables
Researchers identify the variables they will investigate in their research. In experiments, two types of variables are defined: the input variables that are manipulated or controlled (independent variables) and the output variables that are measured (the dependent variables). Independent variables are the causes and dependent variables are the effects (or measures of effects). Independent variables must have at least two levels that can be compared or a treatment condition versus a control condition. Dependent variables must be measurable. Beyond discovering causal relationships, experimental research further seeks out *how much* cause will produce *how much* effect.

Experimental designs
Several designs are available and well described in methods books that can be applied to true experimental designs. Fairly well known designs are for example a 'repeated measures design' and a 'factorial design'.
A repeated measure (or within-subjects design) means that the same variable is measured with the same subjects, under different conditions or at different points in time. Each time individuals participate in the conditions in the experiment, they complete the dependent variable measure, and thus the measure is repeated.
Experiments in which two or more independent variables are studied simultaneously, researchers most often use complex designs like a factorial design. In factorial designs, the levels for each independent variable are combined factorial. Factorial combination involves creating conditions of the experiment by pairing each level of the independent variable with each level of a subsequent independent variable.

Assumptions

Randomized experiments
Some strict rules apply before a randomized experiment can be executed:
Randomized assignment of subjects to the test groups or of test conditions per subject (each person has an equal chance of being assigned to any particular condition).
The independent variables have to be operationalized and have more than one level (e.g. men and women).
It must be possible to hold other variables constant or to assume a random distribution of the variable across the study sample.

Quasi experiments
Generally speaking, quasi-experiments include an intervention or treatment and provide a comparison, but they lack the degree of control found in true experiments.
Experiments are 'quasi experimental' when randomly assigned treatment and/or comparison groups, or 'laboratory control' is not available. Quasi-experimental designs are frequently used in applied research. One of the advantages of quasi experiments is that a researcher can make use of existing interventions in a natural situation. The downside is that it is usually difficult to control for (interfering) external factors because random assignment is not possible.

Output
The data generated by an experiment is quantitative by definition because the dependent variables must be quantitatively measurable. Usually, analyses of variance are the primary statistical technique with which to analyze the data.

Application
Experiments are mainly performed to evaluate cause and effect relationships, for example, the effect of a certain treatment on a person's performance. Experimental designs are also frequently used to compare different situations or new or improved concepts. In this case, different types of concepts are compared with one another. Experiments can be of great use for the Dutch Defence Organization in order to gather quantitative data. Comparison studies in which the effects new (concepts of) equipment and apparel on operational performance are studied helps the decision making process of material procurement and the employment of personnel. Experiments can also serve in the analysis of the effects of tactical changes in physical, physiological, cognitive and tactical parameters in specific operational contexts, on operational effectiveness.

Advantages
An experiment is (one of) the best tools with which to analyze causal relationships.
The internal validity of an experiment is high compared to other data research methods.
If performed well, an experiment is replicable since one can account for the experimental conditions.

Disadvantages
The data that one gathers within an experiment applies to the specific situation in which that experiment was performed. Therefore, it can be difficult to generalize the results to other situations: in other words, the external validity is often low. However, it practice the seriousness of this disadvantage depends on the type of research question.
Performing an experiment is relatively expensive compared to other data collection methods (e.g., questionnaires).

Track record TNO
TNO has a broad expertise in the area of experimental research. TNO has substantial resources (knowledge and facilities) to perform a broad range of experiments.
Human vulnerability studies.
Ballistic impact.
NBC protection, both physical as physiological.
The effect of nutrition on performance.
Experiments performed in an operational context (aiming sights).
Decision-making processes.
Optimal communication media.

Field studies

Description
A field study is a research method that can be used for the description, interpretation and explanation of behaviours, opinions and 'products' of the persons concerned in an existing situation (the field) via direct data collection by the researcher. The researcher does not intervene in the situation. The events and behaviours occur naturally and are not manipulated or controlled by the observer.
Since this type of research method is frequently used when there is little specific information available about a certain research problem, the goal of a field study usually has a descriptive nature.
In choosing what case to study, a researcher may choose a case because it shows different perspectives on the problem, process, or event of interest, or it may be just an ordinary case, accessible, or unusual.
Some researchers performing field studies participate fully in the setting or in the lives of the people they study, by either being or becoming members of the group. Others remain outsiders, purely observers.
The data collection is extensive, drawing on multiple sources of data collection methods (described in later chapters) such as observations, interviews, documents, and audio-visual materials.

Assumptions
Variables are not systematically manipulated.
An object of research should always be studied in its natural environment. ('contextuality').
It is not permitted to reduce the research situation to a few specific characteristics/dimension. The topic of study should be covered as broadly as possible in order to take into account as many confounding variables as possible (holism).

Output data
Field studies often provide qualitative data of specific situations. However, some data collection methods used within a field study can produce quantitative data (for example a survey).

Application
The defence organization can have benefit from this research method because it is extremely suitable for augmenting knowledge of operational functioning of employees. Since it is a relatively unobtrusive research method, a study can be conducted during field exercises or operations in order to gain insight into military procedures or tactics. If, for example, new strategies or equipment are being tested by the military during training, the combination of objective observations by an 'outsider' (researcher) and, for

example, a survey produces a large amount of both qualitative and quantitative information.

Advantages
One can collect detailed information about very specific, real life situations.
Field studies can be a rich source of information.
It is possible to study a phenomenon in great detail.
Can focus on rare, unique, and extreme cases.

Disadvantages
Time consuming.
It may violate people's privacy.
Data collection is vulnerable to biases.

Track record TNO
CRC study of psychological processes during training exercises.
Study on types of psychological operations.
Exploratory study on the use of information operations in the field.

Archival research

Description
For some types of research questions it is simply impossible to conduct an experiment or field study. It is, for example, impossible to infer the relationship between environmental conditions (temperature) and mortality rate from experimental or field studies. Disasters are also phenomena that can't be studied by conducting an experiment or performing a field study. Specific research questions on issues like these, can only be answered by the analysis of existing data.
New data is not being collected in archival research, unlike experimental research or field studies, archival research includes the analysis or integration of existing data. Existing data can consist of (the sediment) of verbal or non-verbal behaviour, in writing, image or sound. The nature of the archive that acts as data sources can roughly be divided in four categories (the data collection methods concerned with these categories will be explained in Chapter 3.3).
Statistical records and other government or institutional records, such as daily temperatures or population growth.
Survey archives of data collected for research purposes by standard survey methods, such as socio demographic information or attitudes on social and political topics.
Written records, or other media such as private diaries, newspapers, sound archives or videotapes.
One of the data collection methods that can be used within archival research is the Meta-analysis.

Assumptions
Analyses of existing data may be performed if:
- there are sufficient and relevant data available to analyze;
- the data form valid indicators of the concepts being studied.

Output data
The output from the analysis of existing data is dependent upon the type of data analyzed and the method used to evaluate or integrate the data. Some methods yield quantitative data, such as the use of statistical records or meta-analyses. Others are more descriptive in their product, such as a case study or the evaluation of written records.

Even these qualitative methods may yield quantitative data if the data is evaluated using quantitative measures (a scorecard method, for example).

Application
The Dutch Defence Organization can benefit from archival research in several ways, like analysis of strategies used during former operations or retrieval of knowledge about the most recent developments on for example training methods by performing a literature study or meta-analysis.

Advantages
High external validity.
Experimenter cannot affect behaviour.
Large volume of data enables relationships to emerge.
Archival research is sometimes labelled as relatively cheap because the researcher does Not have to invest the time and cost involved in data collection and recording. However, retrieving the appropriate data can cost large amounts of time too.

Disadvantages
Researcher has no control over how data are collected.
Important information may not have been recorded and can easily affect the internal validity.
Archival research is not a suitable research method to determine causal relationships.
Correlations between variables can be determined.
Experimenter cannot manipulate behaviour.

Track record TNO
Crowd & Riot control for the Dutch Military Police (KMAR).
Research on social security.
Automotive behaviour (parking).
Historical research e.g. Srebrenica or other conflicts (Belinda Smeenk).

Data collection methods Interviews

Description
Interviews provide in-depth information about a particular research issue or question. Because the information is not quantifiable (i.e., not amenable to statistical analysis), the interview often is described as a qualitative research method. Whereas quantitative research methods (e.g., experiments) gather a small amount of information from many subjects, interviews often gather a broad range of information from a few subjects. An interview is an interactive process, in which the interviewer and respondent can influence each other. An interviewer has the dual goals of motivating the respondent to give full and precise replies, which may take effort (e.g., probing the respondent's memory for specific details or dates), and avoiding biases stemming from social desirability, conformity, or other sources. In general it is the interviewer who must attempt to fulfil these goals in interaction which each individual respondent. The specific tasks of the interviewer, which contribute to these goals, involve creating a positive atmosphere, asking the questions properly, obtaining an adequate response, recording the response, and avoiding biases.

Structured versus unstructured interviews
In a *structured interview*, the interviewer asks a specific set of questions. In the structured standardized interview, these questions are printed and the interviewer

asks or reads the questions in a specific order or sequence. Each question has been carefully pre-tested to express the precise meaning desired in as simple a manner as possible. In the *unstructured interview*, there are no specific questions or guidelines for the interviewer to follow. Thus each unstructured interview is unique. Unstructured interviews provide considerable flexibility but at the expense of stability of the interview data.

Types of interviews
In the *focused interview*, the main function of the interviewer is to focus attention on a given experience and its effects. Interviewers know in advance what topics or what aspects of a question they wish to cover. Somewhat similar to the focused interview is the *clinical interview*, the primary difference is being that the latter is concerned with broad underlying feelings or motivations or with the course of the individual's life experiences rather with the effects of a specific experience. In the *non-directive interview*, the initiative is more in the hands of the respondent. Although interviewers are expected to ask questions about a given topic, they are instructed not to bias or direct the respondent to one rather than to another response. In this form of interviewing the function of the interviewer is simply to encourage the respondent to talk about a given topic with a minimum of direct questioning or guidance.

Assumptions
Research using interviews assumes that:
- respondents are able to answer the questions posed to them;
- respondents are willing to cooperate, and
- the research question of interest can be answered using the type of data resulting from interviews.

Output
The data resulting from interviews is generally qualitative, that is to say descriptive. This is particularly the case with unstructured interviews. In order to analyze this type of data, methods are used to categorize the information so it can be quantified.
When interviews are structured and when close-ended questions are used, the resulting data is quantitative. Many methods are available with which the data can be analyzed. The choice of method depends upon the way interviewees are able to respond to the questions (for example, in terms of measurement scale).

Application
Interviews are particularly useful in exploratory situations. That is, when research questions cannot be stated in any great detail because not enough is known about the phenomena being studied.
When the topic of study is ambiguous or difficult to succinctly clarify in a written questionnaire, interviews are often helpful.
When in depth information is desired regarding the topic of study, which cannot be achieved with a written questionnaire, interviews are preferable.

Advantages
The interviewer has the ability to notice and correct misunderstandings, to probe inadequate or vague responses, and to answer questions and allay concerns, which are important in obtaining complete and meaningful data.
The interviewer can control the context of the interview, including the possible biasing presence of other people.

Personal interviews can attain the highest response rate of any survey technique. Moreover, a face-to-face interviewer can establish a good rapport and motivate the respondent to answer fully and accurately, again improving the quality of the data. In unstructured interviews the interviewer can control the order in which the respondent receives the questions, something that is not possible in written questionnaires.

Disadvantages
As a result of the intense contact between interviewer and respondent, interviewer effects may occur that can be detrimental to the data. The interviewer's expectations or personal characteristics (such as gender or race) can influence responses.
Personal interviews are costly because interviewers need to be hired and trained; travel expenses can be substantial; and interviews might be restricted to a fairly small geographic area because of the logistical problems of sending interviewers long distances.
When the content of interest might prove embarrassing or threatening to the respondent or is viewed as private or personal, direct questioning may elicit deceptive responses or refusals to answer. The basis on which achieving valid responses to all sensitive questions (and non-sensitive questions as well) depends, is the interviewer's rapport with the respondent. Skilled interviewers encounter remarkably few refusals to reply. There are two primary sources of error in the interview: those pertaining to the validity or meaning of interview data and those pertaining to the dependability or reliability of interview data. The tendency to draw general conclusions about an individual based on the limited data of a first impression limits the meaning and accuracy of interview data. Furthermore, the predictive validity for interview data varies widely (i.e., the ability to generalize results to similar situations). The reliability of interview data has been measured primarily in terms of agreement among interviewers on relevant variables. The more structured the interview, the more interviewers agree.

Track record TNO
TNO has a substantial amount of experience with interview research. A few examples are:

- performance and satisfaction in teams;
- experience with information operations;
- the effects of psychological operations.

Data collection methods Observations

Description
Observation is a method by which information on behaviour can be collected through watching and recording what subjects do in situations of interest. Observation makes use of a more naturalistic setting than is available with other types of methods, such as surveys or interviews (i.e., the behaviour is performed in a natural way in natural surroundings). This is the result of the relatively unobtrusive nature of observations on the one hand (observations usually do not disturb the subjects while they are performing their behaviour), and the potential for insight into behaviour which may be difficult for a participant to describe on the other. Observations occur along a continuum ranging from complete immersion in the group being observed (infiltration) so that the subjects of the observation are not aware they are being observed, to complete transparency in which the subjects know they are in a setting in which their behaviour is being observed and who is doing the observing. Somewhere in the middle of the continuum are, for example, observation strategies such as may be used when observing the number of people who visit a public place. In this case, no attempt is made to hide the fact that

subjects are being observed (the observer may be seated in clear view, obviously making notes), but it is not announced to those being observed either.
Informal observations can be made in almost all situations, but observations are *scientific* when.
The observations serve a formulated research purpose.
The observations are deliberately planned.
The observations are systematically recorded.
The observations are subjected to checks and controls regarding validity and reliability.
Generally speaking, we can distinguish between two types of observations: *qualitative observation* and *quantitative observation.*
In qualitative observation, the primary goal of the study is usually not to collect data as such, but to generate hypotheses in an exploratory manner, which may function as input for other, more structured future studies. This may be done using participant observation, in which the observer 'infiltrates' the group that is being observed and does not make formally known that he/she is an observer or that the subjects are being observed.
In quantitative observation, the goal is to test a hypothesis using the systematic tallying of behaviours or other information of interest. In quantitative observation, behaviours may be directly observed and tallied – or counted – according to a pre-determined category system, such as the number of times a soldier in the field consults a compass or other localization device. Behaviour may also be assessed by examining the frequency of a particular piece of information not specifically produced within the limits of the study (in terms of either time or space).

Observations may be registered via:
Field notes in which the observer notes everything he or she observes, in an open, descriptive format (i.e. not constrained by categories or other registration structures). Field notes may be, for example, written notes or verbal recordings.
Checklists or similar tools which allow the occurrence of specific behaviours to be tallied and quantified.

Assumptions
Observations can be used as a method of data collection if.
Observable measures indicative of the construct of interest can be defined.
A suitable setting for observation can be found in which the behaviour occurs frequently enough to make registration worthwhile, and
Observers can be trained to accurately identify the relevant behaviours when they occur.

Output
Depending upon the type of observations conducted, different types of data output are possible. When observations are qualitative, qualitative data is the result, which is generally descriptive in nature. Analysis techniques are available through with this type of data can be categorized, however, the reliability of such a resulting quantification is dependent upon, for instance, the number of observations.
When observations are quantitative, the resulting data is numerically quantified, though the applicable measurement scale (nominal, ordinal, interval, and ratio) may differ, depending on the protocol used to score the observed behaviours.

Application
Observations are used to study overt behaviour. When the goal of a study is to understand what people (or animals, for that matter) do in a particular environment or in response to a particular stimulus, and the use of a self-report measure is not ideal (monkeys cannot give interviews), observations are a preferable method.

Observations can be used to collect data in situations in which the concept of interest can be operationalized in terms of overt behaviours that can be perceived by an observer. For example, it is possible to indirectly assess the influence of a peace-keeping force on the local population by counting the number of weapons turned in during a weapons-for-cash campaign.

Advantages
It is possible to study and describe naturally occurring events in their natural settings.
Respondents are relatively unaware that they are being studied.
Activities can be studied that are difficult for respondents to describe (such as nonverbal behaviour) or that respondents feel uncomfortable talking about (compliance with rules and regulations).
Observations are well suited to research in which measuring the behaviour of interest would otherwise affect the performance of the behaviour.
Observations can be used in situations in which data collection via other methods is relatively difficult (e.g. the group of interest cannot be expected to fill in questionnaires or give interviews).
Observations can be made in the field, but are also suitable for use in a laboratory setting.
Observational studies, depending on the way the study is designed, can be carried out for a relatively low budget.

Disadvantages
Due to the subjective nature of much observational research, the *reliability* of the observations may be lower than desired.
An observed behaviour is intended to be indicative of another, more abstract construct. If the behaviour is indeed a good indicator of that construct, the study has good *validity*. However, observations measure constructs in an indirect manner by their very nature. Consequently, there is a considerable risk that the observed behaviour is actually an indicator of a dimension other than the construct of interest.
Observations made without the consent of those observed may pose *ethical* problems. Factors such as the identifiably of those observed, whether the subject would actually want to be observed or not and the consequences of the results of the study for relevant individuals must be considered.
In situations in which the observer's presence is either too obvious or too disrupting to those being observed, observation is not the method of choice.

Track record TNO
We have conducted many studies in the past using observational methods. Examples are:

- Evaluation of CRISISLAB, a crisis management training simulation used by the Netherlands Air Force.
- Observations of training exercises for crowd and riot control units held by the Netherlands Military Police (Koninklijke Marechaussee).
- Evaluation of the safety of standing in football stadiums.

Data collection methods Surveys

Description
When the primary goal in research is not to describe causal effects, but rather to answer questions about the distribution of and relationships among characteristics of people as they exist in their natural settings, one can do survey research. In doing survey research, one collects data from a certain population, or a sample of that

population, to measure the relative incidence, distribution, and interrelations of certain characteristics, attitudes and behaviours. The term population refers to the aggregation of people to which the researcher wants to generalize. Survey researchers typically gather their data in the form of verbal or written responses to predetermined questions. These questions are the same for all respondents (*standardized*) and, as in contrast to experiments, there is no manipulation of variables.
Surveys are often used to measure what people think about certain topics or objects, such as their work circumstances, government policy, or the quality of a product. In these examples the respondents are asked *directly* for their personal opinions or attitudes. Surveys can be used to measure actual behaviour or factual information. In this case, information is obtained in an *indirect* manner (i.e. the behaviour itself is not be measured, only respondents' reports of their behaviour). When responses are indirect the reliability of the data may suffer: respondents can make mistakes, lack information or have the tendency to give socially desirable answers. For example, when the survey concerns undesirable behaviour, such as driving while intoxicated, respondents may be honest about their real behaviour.

The questionnaire
An essential requirement for developing good questionnaires is to have a clear conceptual idea of just what content is to be measured. The structure of a good questionnaire is characterized by three important elements: 1) *the wording of the questions*, 2) *the wording of the answers* and 3) *the order of the questions*. The wording of the questions is perhaps the most difficult and important task in questionnaire construction. Improperly worded questions can only result in biased and otherwise meaningless responses. Attitudes, for example, are particularly subject to biases caused by wording. When wording questions one needs to take into account language and terminology, ambiguous questions, suggestive questions, negative questions, questions that ask more than one topic, or questions that are open to multiple interpretations.
When it comes to the way the questions have to be answered there are also different possibilities. There are two basis question forms: *open-ended* and *closed-ended*. Open-ended questions allow the respondent to answer in an unconstrained way, because there is no need to choose between different alternatives (for example, asking simply 'What is your age?'). Closed-ended questions, on the other hand, present two or more alternatives, and the respondents select the choice closest to their own position (e.g., 'What is your age?' 0-24, 25-49, 50-74). One can ask questions that can be answered with a simple 'yes' or 'no', but one can also give a list with different alternatives. It is also possible to ask respondents to respond on a scale representing a certain dimension. A common response scale, often used in attitude research, represents the dimension of agreement versus disagreement.
When a researcher uses closed-ended questions, he has to think carefully about the number of alternatives, whether or not to present a middle option, providing the response options 'do not know' or 'no opinion' and the way in which the alternatives are presented. It is advisable to always pre-test a questionnaire in a small group of people before using it on a larger scale.
The order in which questions are presented is important because questions that come earlier in a questionnaire may affect the interpretation of questions positioned later. Furthermore, particularly if a questionnaire is long, respondents may weary of answering questions and not answer questions later in a questionnaire as thoughtfully as questions presented earlier.

Verbal or written
Using a structured questionnaire, data can be gathered in two ways: 1) with written questionnaires or 2) with personal interviews. Written questionnaires can be web-based or sent by mail. Personal interviews can be done face-to-face or by telephone. In both cases the interviewers need to be well trained and instructed. Each mode has specific advantages and disadvantages that the researcher needs to evaluate in terms of their suitability to the research question, the specific population being studied, and relative cost.

Survey designs
In doing survey research, one always needs to carefully consider the choice of survey design. This refers to the way the survey is conducted in terms of recruiting respondents from comparison groups, the number of times a survey is conducted, and so forth. The most straightforward design in survey research seeks to establish the incidence and distribution of characteristics or the relationships among characteristics. In studies with such limited goals, the only real concerns are if the population sample is representative of the population from which it was taken, and that the study accurately measures the relevant characteristics. Such a design may consist of only one group of respondents, and only one measurement moment. Though suitable for some simple research purposes, more complex research questions need more complex designs, particularly when the study seeks to establish causality between two or more variables. For such studies, various designs are available, three of which are briefly described.
A common design for survey research that attempts to explain and interpret the relationships between characteristics is the *static-group comparison*. This design enables the researcher to study differences between two or more groups, such between men and women, people of different ages, with different incomes or from different ethnic backgrounds. Using a static-group comparison, we can better understand how different variables are linked with group membership, however, this design cannot be used to establish causality.
One way to establish causality is the *time order criterion*. That is, if the value of a particular variable changes over time (e.g. income) in concert with changes in another measured variable (e.g., achieved educational level), we can conclude that changes in one variable cause changes in the other (e.g. higher levels of education lead to increased income). To meet the time order criterion for establishing causation, we can use the *panel survey design*. This design takes into account time and changes over time by collecting data at two or more points in time from the same subjects each time.
Sometimes survey researchers are unable to gather data by using the same subjects each time. In that case the researcher needs to take new samples from the same population over a certain period of time, which is called *cross-sectional, pseudo panel design*. When the researcher has definite ideas about which variables precede which others in terms of time, causality can be established, even using different respondent samples.

Assumptions
The sample taken from the population of interest is representative of that population.
Respondents are able to answer the questions posed to them. For example, it is not useful to ask people what their blood pressure is, or what the length of their REM sleep is, because people have no insight into such processes.

Output
The data resulting from surveys are almost always quantitative. As such there is a variety of suitable analysis techniques from which to choose depending on the measurement scale used.

Application
Survey research is used to collect data from a certain population, or a sample of that population, to measure the relative incidence, distribution, and interrelations of certain characteristics, attitudes and behaviour. In many cases survey research is aimed at establishing whether two variables co vary, and under what conditions they co vary. In general, surveys are less suitable for causal explanations, because variables are not manipulated in order to test causality (though it can be done with specialized designs). However, questionnaires, such as are used in a survey, can be a part of an experimental research design. Survey research is also used to measure whether there are changes over time, or between different groups. Examples of survey research include:
The Netherlands army makes frequent use of questionnaires when it concerns staff matters, selection and training, the gathering of experiences in the area of operation, attitudes and opinions about the organization or new equipment.
Surveys are used to measure the effects of psychological operations in the area of operation, such as attitudes towards the peacekeeping force.

Advantages and disadvantages
Survey research has many advantages, which all have their downsides:
It is not difficult to do survey research. However knowledge about constructing good questionnaires, sampling and analyzing data is indispensable.
Surveys need not be expensive. It depends upon the number of respondents (and whether they cooperate voluntarily or receive payment) and the way in which the data are gathered (face-to-face, telephone, written or web-based). For a simple survey, paper and pencil can be sufficient.
Surveys can be done relatively quickly, since it does not take a lot of time to make a good questionnaire, and even web-based questionnaires are not difficult to make nowadays.
Surveys do not require a lot of effort on the part the respondents. At most, respondents must spend some time answering the questions. The number of questions that one can ask is not infinite, though. At some point respondents' concentration decreases, they get tired or distracted, which can result in less reliable outcomes.
The resulting data describes the phenomenon of interest in quantitative terms.
As mentioned earlier, survey research assumes that the respondents are able to answer the questions. This requires a certain amount of knowledge, insight into oneself and honesty. Furthermore, it must be possible to approach the respondents, and they must be willing to cooperate. For example, it will be very difficult to do survey research among hostile opponents.

Track record TNO
TNO has a lot of experience with survey research. A few examples are:
- the employability of observers;
- team competencies and morale;
- stress and physiological constraints;
- performance and satisfaction in teams;
- the effects of psychological operations.

Analysis of pre-existing data

Description
This data collection method is, in fact, a collection of various ways to do archival research. Specifically, what are central to this method, are the various sources from which input data for archival research may be obtained. Though many more sources exist, in the present chapter, we address five of the most commonly used sources: statistical records, written records, literature study, Meta analysis, and case study.

Statistical records
This particular source refers to the data available from bureaus and organizations that record statistical information regarding various phenomena. In the Netherlands, for example, the Central Bureau of Statistics (CBS) records information about the demographic make-up of the population. If a study examines the effects of changes in attitudes toward foreigners on immigration, one could consult the CBS for information on the number of foreigners (in both absolute and relative terms) in the country across a period of years. In addition, schools, health agencies and businesses keep statistical records of various types. Particularly useful are also data acquired from national census taking.
Similar to statistical records are survey archives. Here, giant surveys are (repeatedly) conducted in order to collect data on various topics over a longer period of time. These surveys may address such issues as attitudes regarding political or social issues, religion or financial behaviour.
Characteristic of statistical records is that, first, they are usually collected for purposes other than the particular study at hand: the CBS does not collect demographic data in order to compare changes in attitudes with ethnic make-up of the population. Second, sometimes the existing data must be 'translated' into indices indicative of the concepts that are being studied. For example, if one is interested in relative deprivation[1] – data on which is not directly available from statistical sources – one must look for secondary indices of relative deprivation such as differences in credit card debt in various socio-economic groups. Third, conclusions of studies using statistical records are particularly susceptible to alternative explanations.

Written Records
Written records refer to documentation created for a purpose other than research. Examples are speech transcripts, diaries, non-fictional literature, or mass communications. The analysis of such information can yield insights into, for example, social climate, *zeitgeist*, important themes or problems in society. To illustrate, analyzing the content on Arab web sites provides insight into the way Arab countries view their position in the world and how they interpret Western behaviour.

Literature study
In a literature study published information is collected, analyzed and integrated in order to acquire a relatively complete view of a particular topic. Sources are generally published, and may be either electronic or hard copy. Often, use is made of books or articles from scientific sources, the mass media, the popular press, web sites etc. The goal of a literature study is to acquire an overview of what is known about a particular topic. Often, a literature study is followed by an empirical study in which new data are generated, and that is intended to further develop the existing understanding of the phenomenon being studied.

[1] Relative deprivation is the feeling that one is deprived of desired resources, which are available to others.

Meta analysis

In much scientific research, conflicting results may be found across studies: results cannot be replicated, different research paradigms lead to different results etc. In sciences that rely on conclusions based on statistical probabilities, these differences may be the result of statistical coincidence. In order to tease apart coincidence and the 'real' effect, a Meta analysis can be used. A Meta analysis, in this sense, may be considered an extension of or a special type of literature study.

A Meta analysis is (statistical) method used to abstract information about higher-order effects from a collection of primary data sources (empirical studies). Specifically, as many studies as possible examining a particular concept are gathered. The relevant statistical information from each study is noted and mathematically combined, thus yielding a composite score. This integrated score is a better (more powerful) indicator of the relationship between the examined variables than the relationships described in the individual studies.

Case study

In a case study, one analyses in detail one situation in order to achieve insight into the relationships between relevant variables. In the case of the analysis of existing data, no new observations are carried out in order to assess the case, but rather existing reports detailing the situation of interest are thoroughly analyzed. Though such a method may provide a detailed view of the processes in that one particular instance, because case studies are 'one-shot' events, the results of such a method lack reliability. Because there is no comparison with other instances, it is impossible to conclude that the identified relationships are robust or if they are characteristic of only this one situation. Case studies may be practical, however, in preparation for a larger undertaking: as a pilot study, in other words. In this case, hypotheses can be preliminarily tested to ascertain whether or not one is 'barking up the wrong tree.' Promising case study results can be taken as an indication that conducting the main study may be a worthwhile pursuit.

Assumptions

Analyses of existing data may be performed if:

- there are sufficient and relevant data available to analyze;
- the data form valid indicators of the concepts being studied.

Output

The output from the analysis of existing data is dependent upon the type of data analyzed and the method used to evaluate or integrate the data. Some methods yield quantitative data, such as the use of statistical records or Meta analyses. Others are more descriptive in their product, such as a case study or the evaluation of written records. Even these qualitative methods may yield quantitative data if the data is evaluated using quantitative measures (a scorecard method, for example).

Application

The analysis of existing data is generally used to study phenomena on a large scale. Census data can be used to draw conclusions about the make-up of a whole society, Meta analyses are used to identify higher-order effects by combining many smaller studies and literature studies are done to get and integrated overview of what is known about a particular topic. In addition, existing data may be analyzed when studying the phenomenon is difficult, prohibitively expensive or poses ethical problems. To illustrate, consider studying the effects of non-lethal weapons (NLW). Even though the effects of these weapons are designed to be less than lethal, studying them is tricky because, for example.

It is difficult to design a study that is both naturalistic and in which the data is obtained under controlled circumstances.
Though the effects may not be lethal, they may cause injury that, in some cases, may be permanent (this is primarily one of several ethical problems), and there is a large amount of anecdotal data on the effects of NLW.

Advantages
Making use of existing data allows the researcher to assess the impact of natural events.
External validity is high because the respondents are unaware of the research in which they are participating.
Using existing data is often economical because time and money are not needed to execute a study.
Useful information is often collected *en passant* by organizations as a matter of everyday operations, and it is often collected repeatedly.
Trends over time are possible.
The analysis of existing data is well suited to the investigation of large-scale or widespread social of natural phenomena.

Disadvantages
Internal and construct validity are often low.
Relationships between variables may be spurious in which case the collection of addition data is warranted.
Because the researcher does not have control over the collection of the data, there is no control over the particular variables that are measured, the presence of biases and potential threats to validity and reliability.
Because the data may be subject to incompleteness, it may be difficult to determine the degree to which the data accurately represent the population of interest.
Finding relevant information as well as information that can be used to rule out alternative explanations can be time-consuming.

Track record TNO
Examples of studies in which TNO has analyzed existing data are:
- a study assessing the role of human factors in Information Operations;
- an evaluation of the effects of non-lethal weapons on humans;
- a review of the factors influencing the success of crisis management teams.

Models and simulation

Search and damage assessment

Description
Search, detection, acquisition, recognition and identification are prerequisites for target engagement. To detect a target, a search is initiated using sensors. After detection, the target is acquired. Acquisition is the repeated detection of a target during several scans by the sensors or over several seconds of a continuous look. By tracking the target the processes of recognition and identification is started. All processes (search, detection, tracking, recognition, identification, and damage assessment) can be quantified within success probabilities. The elements needed for calculating these probabilities depend on the sensors and weapons used, environment, and of course the target itself.

Detection modes and detection models
Different types of sensors are used for detection. Depending upon the nature of the sensor, two types of search procedures can be considered: scanning search in which the search is conducted using a succession of brief glimpses and continuous search in which the target may be detected at any instant of time. Besides detection models, there are search models to locate the precise position of the target in the given area. Examples of search models are exhaustive search, inverse cube law, random search, and heuristic search.

Hit probability
After the target has been identified and recognized, either the shells are fired from guns, or rockets, missiles and torpedoes are launched, or bombs are dropped. The next topic of interest is to determine the probability of hitting the target and this depends, besides other factors, on the errors associated with firing and launching mechanisms. By looking at the probability of hit, the following errors are normally considered: aiming error and ballistic dispersion error. The aiming error may generally arise due to improper levelling, alignment of the weapon, and sensor and human errors. The ballistic error arises mainly due to meteorological conditions and variations in the ballistic characteristics of each shot. It should be pointed out that the ballistic error is assumed to be independent among rounds within a fire engagement whereas the aiming error is dependent. Due to these errors the mean point of impact (MPI) may deviate from the aiming point, usually the centre of the target. The round-to-round dispersion around the MPI is used to determine the hit probability.

Damage assessment
In a number of military OR studies dealing with artillery guns, air-to-surface and surface-to-surface weapons, the probability or the proportion of the area of a target damaged by a weapon or weapons is usually required to be determined. These studies broadly pertain to two categories of targets: point target and area target. Point target is one whose size is smaller compared to area damaged by a single round of the attack weapon, e.g., missile silos, radar installations, small bridges. In case the size of the target is much larger that the area damaged by a single round of the attack weapon, it is called an area target, e.g., city, airfield, harbour.

Input
For the detection models, input is necessary about the **probability of detecting a target**. For all sensor used (including visual means) the probabilities are dependent on distance and environment. This can be assumed to follow a distribution (see assumptions), can be determined by experts or experiments or based on historical data.
For the search models the **target distribution** is needed as input. Again this can be assumed to follow a distribution, can be determined by experts or experiments or based on historical data.
The **round-to-round dispersion** around the mean point of impact is usually represented by statistical distributions. This is used as input to determine the **hit probability**.
For damage assessment the **probability that the target is destroyed** and the **damage function** of the target, will be used as input.

Output
The output of detection models are the **probabilities of detecting** (a single target) within a certain time. The output of search models is the location of the position of the target in an area. And of course the **probability of a hit** is the output of the hit probabilities. The probability or the proportion of the area of a target damaged by a weapon or weapons is the output of the damage assessment.

Assumptions
Concerning search, detection and damage assessment assumptions are made for distributions. With detection models, assumptions are made about the probability of detecting a target. There is often assumed that the number of detections follows a Poisson distribution. Other possibilities are to use an expert's assessment, historical data or experiments.
In search models assumptions are made about the target distribution. For determining the hit probability, assumptions have to be made about the distribution of the round-to-round dispersion and for damage assessment the assumptions are concerning the probability that the target is destroyed.
The cumulative probabilities are calculated assuming independence through total dependence of occurrences using assumptions.

Advantages and disadvantages
With search models the decision maker can decide how much equipment is needed to accomplish the job or how many time is needed for the job. The disadvantage of the traditional search models is that it is based on 'negative information'. In reality it is even possible that no target exists. In that case the outcome should be read as the confidence that no target is present. For instance if the search model delivers a probability of 99% after 72 hours of search and no target is found within 72 hours, this should be interpreted as there is no target present with a risk of 1%.

Application
Search models are used when the aim of search lies within the optimal search strategy. In these cases we talk about Static Distribution of Effort problems [ref. Washburn]. Search models are maybe useful in urban warfare. These methods can be used for every task where the yield is to give information about the environment, the enemy or the consequences of firing a weapon.

Track record TNO
[1] CAEn, a simulation tool for close combat; Barbier; S010259.
[2] IWARS.
[3] SMARTER, a simulation tool for ground based fire support; Kurstjens; S010067.
[4] SCOPE.

Simulation of military systems

Description
Due to complexity in defence systems, it may not be possible to perform experiments to test and evaluate the systems. Consequently, system studies are conducted using models which are abstract representations of one or more physical systems, situations or phenomena. A relative simple model can be solved analytically. In an analytic solution, the desired output is expressed as an explicit function of the input variables. The requirements of developing the model close to the real life system as well as being amenable to simple analytical solution may not always be possible. Also, there are situations where an analytical solution is not usable for further analysis. For example, an analytical solution may lead to an infinite series or complex integrals. In such cases, it is preferable to use an experimental approach, namely computer simulation, to determine the solution of the model.

System simulations can be governed by probabilistic events. Therefore, one needs a mechanism for generating samples from a population with a given probability

distribution. For this purpose, a set of random numbers is required. Large number of truly random numbers can be used, pre-generated by use of random generators and store them into the computer memory. The method of generating a sample of values for the variable following a specified distribution is termed Monte Carlo sampling procedure.

Simulation systems are subdivided in continue system simulation and discrete system simulation. The first one will be outlined in chapter 'Homogeneous and heterogeneous combat models'. In most military systems, events do not occur continuously but at isolated points in time. These are called discrete systems. 'Event driven simulation' and 'time driven simulation' are two approaches for discrete system simulation. An appropriate approach for simulation depends on the nature of the inter-event intervals. Event-driven simulation is appropriate for unequal or random intervals between consecutive events. Contrary to this, if the inter-event intervals are equal then time-driven simulation approach is appropriate.

Military simulations can be subdivided into two groups: weapon system simulations and combat simulation. With weapon system simulations the effectiveness of a specific weapon or sensor is simulated. With combat simulations the cooperation and effectiveness of more weapons and sensors is simulated. Some of these models incorporate synergy, but most don't. Military simulations can be classified into weapon or sensor system, single platform (more weapons/sensors on a platform), task group (more single-platforms with a task), mission analysis (more task groups) and theatre level simulations (more missions).

Input
To get worthwhile results there is information needed about the system which will be simulated. When analysing the damaged area of a bomb for example, information is needed about the distribution of the damage area. Or for analysing the survivability of a tank, the hit probabilities are needed.

Output
The results of the simulation will provide information about the simulated system. This can be the damaged area of the bomb or the 95% confidence interval of the survivability of a tank. The results of the simulation will always be output given the assumptions which have been made.

Assumptions
Depending on the type of simulation different assumptions can be made. For stochastic simulations there will be an assumption about the distribution of the system.

Advantages and disadvantages
The advantage of using simulation is that it can give a representation of a physical system, situation or phenomenon when the model is too complex to determine analytically. Besides that, simulation can be used when it is not possible or desirable to make experiments with the system itself.

A disadvantage is that simulation is a limited representation of the reality because assumptions underlying the model are always made.

Application
The application of simulation has also come up in the previous paragraph. Simulation can be used when determining an analytic solution is too complex and experimenting on the system itself is not desirable.

Track record TNO

[1] Force Structure Model (FSM) – a manoeuvre combat simulation model; Overmaat; S010356.
[2] SMARTER, a simulation tool for ground based fire support; Kurstjens; S010067.
[3] KIBOWI; Borgers; S030305.
[4] IWARS.
[5] Scenario Development; Toevank; S020279.

War games

Description

War gaming can be described as [Dictionary of U.S. Army Terms 1965]:
A simulation of a military operation involving two or more opposing forces, conducted, using rules, data and procedures designed to depict an actual or assumed real life situation.
Combat simulation and war gaming are very closely linked so much so that 'simulation' is often used to refer to both. However, war games are simulations involving human or player interactions. Simulations may be used where this distinction is not so clear. So war game involves human interaction in a simulated war scenario.
Each war game has its purpose, nature and technique of its conduct. War games can be classified based on their purpose as training games, planning games and analytical research games.

Training war games

Training games are essentially meant for training commanders at various levels. The aim of such games is to train practicing commanders in the handling of formations and units of various sizes and the practicing staff in planning for various operations of war of for various contingencies. Training war games include military field exercises as well as computer-assisted training war games.

Planning war games

Planning war games are played essentially to test the effectiveness and reliability of standard operating procedures (SOP), to evaluate existing operational plans or to develop new plans. These may be solo or two-sided games. In solo war games, the commander makes plans, changes his/her role and acts as the enemy commander and tests the plans. This procedure suffers from the obvious disadvantage that the enemy plans are known to the player. In the two-sided war game the plans may be subjected to scrutiny by an outside agency or another commander who has not been associated with the original planning at all. The two-sided game may be played where one of the teams is acting as the sponsor of the plans and the other taking the role of the enemy. Planning war games can also be used when playing against a computer which represents a 'learning' opponent.

Analytical research war games

The purpose of these games is to test concepts and doctrines, and to evaluate the effectiveness of weapons. These games are designed as controlled experiments so that comparisons can be made. Situations are contemplated so that concept under study should form part of the game and with stochastic models the analysis of output is made using statistical techniques.

Input
Just as the input of simulation of military systems, the input will be information about the simulated training, planning, operation or system which will be simulated. This information can be very diverse and is dependent on the kind of war game.

Output
The results of the war games will be information about the situation or system. For the training war game the results will increase the training capabilities of the commander. The planning war game gives output about the effectiveness of a procedure or plan. Analytic research war games will say more about the doctrines or weapon systems.

Assumptions
Just like the input and output, the assumptions of war games can also vary a lot. Examples of assumptions are preconditions about the tested plan or operation. Or for analytic research war games the assumptions are more like the behaviour of a group with a certain weapon system.

Advantages and disadvantages
The advantage of using war games is that it can be used as a tool when experimenting in practise is not possible or desirable.
Just like simulation a disadvantage can be that war games are a limited representation of the reality because there are always made assumptions underlying the model.

Application
The application of using war games is that it can be used as training tool, to test a procedure, doctrine or effectiveness of a weapon.

Track record TNO
[1] CAEn, a simulation tool for close combat; Barbier; S010259.
[2] IWARS.
[3] KIBOWI; Borgers; S030305.
[4] Scenario Development; Toevank; S020279.

Homogeneous and heterogeneous combat models

Description
Homogeneous and heterogeneous combat models model the relationships of the mutual combat strength with the help of a few comparisons. Not only combat strength will be expressed in amount of weapon systems, but also aspects like aggregation, time and space factors are taken into the comparisons.
Homogeneous models are based on attrition warfare. This means that in a fight between two armed forces the number of losses is a constant factor and is independent of the relative strength of both parties. There are diverse variants of this assumption where among other things the strength of the opposition influences the attrition in time of the own units.
On the basis of these models pronouncements can be made about the armed force who will probably win the conflict. To determine this, so called combat termination rules are necessary like the absolute or relative wear in percentage of original strength. Ascertain from these rules will be determined when the fight is regarded as over.
Differential equations can be formulated where the strength of the parties are dependent on the time and strength of the opponent. On the basis of these equations and the combat termination rules it is possible to determine who will win the conflict and what the strength of both parties will be at the end.

Empirical studies have proven that more factors can end the conflict besides the combat termination rules. The most important factors are in this case the tactic, the relative combat strength and the measure of attrition.
In homogeneous models all used weapons or combat units are equal in the combat. The basis of the heterogeneous combat models is the homogeneous combat models. The difference is that in heterogeneous combat models several weapon systems can be modelled.
The Lanchester model is an example of a homogeneous combat model. Lanchester models serve as a fundamental model in developing theories of combat and for calculating attrition rates in military operations. The overall concept is based on a simple mathematical expression where the attrition rate of the Blue force is equal to the product of the effective firing rate of the Red force and the number of the Red combatants (or weapons).

Input
An important aspect of combat modelling is to determine the rules governing combat termination. These rules are input for the models and can be determined by experts.

Output
On the basis of these models there can be said which party will probably win the conflict.

Assumptions
As mentioned in Section 8.2 there are combat termination rules needed as input for the model. These rules are also assumptions of the model.

Advantages and disadvantages

Application
These models can be used when information has to be given about the effectiveness of a combat, such as the amount of enemy casualties.

Track record TNO
[1] IWARS.
[2] Force Structure Model (FSM) – a manoeuvre combat simulation model; Overmaat; S010356.
[3] SCOPE.
[4] KIBOWI; Borgers; S030305.
[5] CAEn, a simulation tool for close combat; Barbier; S010259.

Cost effectiveness analysis

Description
Selection of a weapon or equipment for acquisition from available systems is an important class of problems encountered by defence decision makers. The selection of a weapon system depends on its effectiveness and costs. The evaluation of effectiveness is usually complex since it depends on a number of factors affecting the performance of the system. For example, the effectiveness of an artillery gun system primarily depends on its rate of fire, lethal radius and accuracy. Given the alternative gun systems, one gun system may be better than the other with respect to the rate of fire but may have less lethal radius and accuracy. To compare the effectiveness of alternative gun systems, the analyst, defines a Measure of Effectiveness (MOE) and evaluates it for available gun systems.

For estimating system cost, the systems are divided into two categories: systems which are to be developed and those which already exist.
For cost effectiveness analysis, the following approaches are adopted:
Fixed Effectiveness Approach: the effectiveness level is fixed and an attempt is made to determine the alternative which has less costs.
Fixed Budget Approach: In this approach the budget is fixed and an attempt is made to determine the alternative which has maximum effectiveness.
Figure of Merit Approach: In some cases, it may not be possible to fix either the effectiveness or the cost. In such cases if E_i and C_i, i=1,2,...,m, are the effectiveness and system cost for the ith alternative, the ration E_i/C_i gives the effectiveness of the ith system per unit cost and is called the 'figure of merit'. The best choice is the one with the highest value of the figure of merit. Making a plot of the effectiveness and costs can give a good insight into the analysis of the different alternatives.

Input
This method will be applied when a choice has to be made between a number of systems. For each system the effectiveness will be determined. The needed input will be the values of each systems by which the effectiveness can be calculated.

Output
The output by using cost effectiveness analyses will be an advice which system is best given the assumptions concerning effectiveness and costs. This means for the different approaches the output will be:

- Fixed Effectiveness Approach: the costs per system given the minimum effectiveness.
- Fixed Budget Approach: the effectiveness per system given the maximum costs.
- Figure of Merit Approach: the effectiveness of each system per unit costs (the figure of merit).

Assumptions
The next assumptions are made for this method:

- It is assumed that every criterion identified for analysis is quantifiable and the quantification is unique.
- It is assumed that all criteria ca be related to one super criterion (effectiveness) and the evaluation can be made on that basis.

Advantages and disadvantages
Comparing to other analyses is cost effectiveness analysis a relative simple method which gives a good insight into the comparison of different systems concerning their costs and effectiveness.
The techniques to conduct cost effectiveness analyses also have some fallacies, which are stated below:

- Sole criterion fallacy: in cost effectiveness analysis a single criterion is used as the basis for evaluation. It is difficult to decide a single measure of effectiveness which considers all these parameters. Mostly this is not possible.
- Ratio fallacy: with the figure of merit approach, only the value of the effectiveness/costs is used while the actual magnitudes of the numerator and denominator are ignored. It may be preferable to use fixed effectiveness approach of the fixed budget approach wherever possible.
- Quantification fallacy: Some criteria are difficult to quantify as for example safety. Inter-relationship Fallacy: the second assumption mentioned in Section 1.4 may not be true because the underlying criteria are not independent of each other.

- Fallacy in cost or effectiveness Approaches: fixing the budget or effectiveness inappropriately may lead to wrong conclusions.
- The number of missions envisaged: for defence systems it may not be possible to assess the number of missions envisaged during the planning period. Cost effectiveness analysis is quite sensitive to this element.

Application
Cost effectiveness analysis can be used when one likes to make a choice between different systems.

Track record TNO
[1] FEL-SALDO; Marcel Smit; S020106.
[2] SUITCASE; S010218.
[3] LCC, Life Cycle Cost Analysis, Marcel Smit, S010158.
[4] SMP.

Multiple Criteria Analysis

Description
Multiple Criteria Analysis (MCA) is an analytic approach for decision- and decision-making problems. With MCA a number of alternative options (concrete or abstract by nature) are identified, judged and compared with each other. The identifying, judging and comparing of the alternatives is done with the help of a (possibly hierarchic) structured set of aspects of judgement (goals, contexts, criteria, attributes). These aspects are mutually weighed to get an authorized final judgement of the alternatives. Consider for example the situation in which acquisition of weapons is being planned. Weapons for acquisition have to be evaluated on several criteria, e.g., suitability to own forces, maintainability and cost. A criterion is a measure of effectiveness and is the basis for evaluation. Some of these criteria may be conflicting in the sense that the best suitable weapon can involve maximum costs. The criteria are usually not equally important and different stakeholders may have different opinions about the importance of each criterion. Because of the subjectivity of the importance of the criteria it is important to analyse the effect of changing weights on the final results. This is called sensitivity analysis.
With MCA the parties get insight in each others arguments for choosing one of the alternatives above another. There are two types of MCA: discrete MCA and continuous MCA. With discrete MCA the alternatives are known and separately definable. With continuous MCA the alternatives are implicitly defined by preconditions (like mathematical programming).
Properties of MCA are:
- there is more than one criterion;
- there are conflicting criteria of differing importance to the decision makers;
- there are different units of measure;
- (often) there is no optimal solution with respect to conflicting criteria;
- (often) there are limited alternative solutions.

In the division Operations Research and Management of TNO Physics and Electronic Laboratory a tool is developed to support Multiple Criteria Analysis. The tool is called TOPSYStem. There is also a system to support group discussions. The aim of the division's support is to achieve a transparent process that leads to argued and definable decisions where all factors of influence and interest are taken into account.
Due to a lack of adequate quantitative information about performance of different systems, one may have to depend on judgment of experts rather than analytic methods. Techniques like Delphi method, decision matrix approach and forced decision matrix

approach, analytic hierarchy process have been found useful to analyze this class of multiple criteria decision making problems. These techniques are briefly discussed.

Delphi method
The Delphi method is a commonly used method which facilitates the use of the opinion of experts. The method is not explicitly focused on the support of multiple criteria problems.
The Delphi method is characterized by three features: anonymity of the experts, iteration with controlled feedback (where there are more rounds of questions) and statistical group response (where the median is taken as consensus). This method is conducted in four rounds.

Decision matrix approach
The decision matrix approach can be used to choose between different alternatives. The different alternatives are judged quantitatively on the criteria. Two aspects in this approach are debatable. The first aspect is determining the relevant criteria. The other aspect is about the assignment of weights to various criteria.

Forced decision matrix approach
A variant of the decision matrix approach is the forced decision matrix approach. In this approach, the ratings are given in terms of 0 and 1. All the contractors are compared pair wise with respect to each criterion, e.g., if contractor A is better than contractor B in regard to value of the contract we give a rating 1 to A end 0 to B. The results of the pair wise comparison of the contractors for the four criteria are obtained and the rating of each contractor is evaluated as rating = total score/number of comparisons. A possible problem can be the inconsistently of the pair-wise comparisons (A>B, B>C but not A>C).

Analytic hierarchy process
This technique follows a similar procedure as the forced decision matrix approach but allows a wider range of values in comparison of alternatives. The method also uses pair-wise comparison both for prioritizing alternatives and for weighting criteria but the degree of preference can be indicated. Further, the criteria are structured in a hierarchic tree.

SMARTS
Swing weights into The Simple Multi attribute Rating Technique (SMART) is a MCA implementation of the additive weighting method. Swing weights have become a popular procedure for assigning weights to a criterion based on how much that criterion can influence performance (its range or 'swing' in values) relative to the criteria with a maximum swing in values. For example, costs might be important in an absolute sense, but if all the alternatives are similar in costs, then that criterion will be less important relative to others being considered. Because swing weights represent a ratio of the valuation of the difference in preferences between any criterion and the most influential criterion, they are also referred to in the literature as ratio-scaled preference judgments.

Input
Input for a Multiple Criteria Analysis is in the first place the set of **alternatives** and the set of **criteria**. For example with the choice which car to buy the possible cars and the criteria (the price, the fuel consumption etc.) need to be known. In the MCA these criteria are mutually weighed. The **weights** are needed as input and can be determined by the decision maker or by experts.

Output
The output of MCA consists of a recommendation which alternative or alternatives may be better than the others. This recommendation is based on the critical results of the aggregation of input information, but also on a sensitivity analysis.

Assumptions
Particular requirements which are made for MCA are:
- operable: it can be filled in and used by reasonable support;
- decomposable: parts of the problem can be considered separately;
- measurable: degree of reaching the objective should be able to be measured with the help of the attributes.

For the alternatives which are absorbed the assumptions are:
- they are mutually different;
- they can be implemented;
- they can be judged;
- they contribute to the objective.

Advantages and disadvantages
The goal and also an advantage of MCA is that the parties get insight in each others arguments for choosing one of the alternatives above another.
The weighing of the criteria is on the basis of the opinion of experts. The subjectivity of the method can be seen as a disadvantage.

Application
MCA will be used to solve a problem where different alternatives are possible. MCA is suitable for problems where the goal is to get more transparency of the process and to get a recommendation of which alternative of which alternatives are better than others.

Track record TNO
[1] TOPSYStem; Wijnmalen; S010249.
[2] Group Systems (GFR), Wijnmalen.
[3] Replacement YPR.

Analytic optimization models

Description
There are many different optimization models. An example is a model to solve resource allocation problems. Resource allocation models optimally use resources to reach a certain goal where different conditions are taken into account. Examples of these problems are: weapon mix problems, weapon deployment problems, weapon target allocation problems, sortie allocation problems. Besides resource allocation models, there are for instance transportation problems and assignment problems.
The above problems can be solved by optimization techniques. A couple of these techniques are explained below.

Linear programming
Linear programming is applied in solving optimization problems in which the objective function and the constraints are linear functions. The application of linear programming increased considerably after the development of the simplex method. This is a well-known algorithm using only function value information. An advantage of the simplex algorithm is the small number of calculations that is needed to initialize the algorithm.

Integer programming
By using linear programming the solutions may have some fractional part. It may not be possible to implement the solution in real life situations. For example, the solution obtained by using linear programming can obtain 4.11 missiles. Since the weapon system cannot be partitioned, the commander can deploy either 4 or 5 missiles. This allocation, however, need not be feasible or optimal. To solve such problems, a scientific approach called integer programming has been developed. There are several methods to solve such problems. Examples are cutting plane algorithms as well as branch and bound algorithms.

Multi objective programming
The above techniques have a single objective function. However, situations can be easily visualized where the decision maker may have more than one goal to optimize. For example a weapon target allocation problem where the objective is to maximize the total kill potential of air defence weapons against all attack weapons and minimize the sum of the shortfalls from the required kill potential against the attack weapons. This problem combines the two objectives functions and since each of them is linear, the problem reduces to a multi objective linear programming problem or a weighted linear programming problem.

Dynamic programming
The dynamic programming technique is based on the principle of optimality. This can be based as: an optimal policy has the property that whatever be the initial state and the initial decision, the remaining decisions constitute an optimal policy with regard to the state resulting from the first decision. The principle of optimality indicates that there is referring to a decision process that can be partitioned into distinct stages of decisions. The system at each stage will have a well-defined state which after implementation of the decision will lead to some new state.

Nonlinear programming
Situations may arise where either the objective function or the constraints may not be linear. Three possibilities may arise:
1 The objective function is linear while some or all of the constraints are nonlinear.
2 The objective function is nonlinear while all the constraints are linear.
3 The objective function is nonlinear and some or all of the constraints are nonlinear.
For solving these problems nonlinear programming techniques can be used. Like linear programming, nonlinear programming is an optimization technique dealing with continuous variables.

Input
The input of optimization models contains information about the problem. For a resource allocation problem for example information is needed about the resources and the allocations and the cost, time or distance to assign them. For transportation problems the possible means of transportation, the routes and the costs are needed.

Output
The output of the optimization model will be an analytic optimal solution. The solution can be a solution in terms of optimal means of transportation, or optimal assignment.

Assumptions
There are no general assumptions with optimization models.

Advantages and disadvantages
In general, the advantage of optimization models is an analytic approach which results in an optimal solution (if the problem is solvable). This is in contrast with for example simulation models or war games. A disadvantage is the complexity of the model in particular when a lot of variables are involved.
Linear or multi objective linear programming is in general less complex than integer programming, because there is no restriction that the solution has to be a round number.

Application
Optimization models will be used when the problem can be analytically modelled. The above discussed optimization techniques don't have to be used separately. The application is very dependent on the specific problem.

Track record TNO

Heuristic optimization models

Description
There exists a class of combinatorial problems with inherent complexity that any technique to optimally solve problems requires too much computational effort. The exact solution of these problems may be obtained through optimization algorithms as spoken in the previous chapter. If the problem is not amenable to optimization algorithms due to large computation time, another option is to go for solutions which can be obtained quickly at the risk of sub-optimality. These are called approximation or heuristic algorithms.
Heuristic algorithms are very efficient in handling combinatorial explosion encountered in situations where choices are sequentially compounded, leading to a large number of alternatives. Some of the important techniques are mentioned below.

Greedy algorithms
Some optimization problems can be solved using a greedy algorithm. A greedy algorithm builds a solution iteratively. At each iteration the algorithm uses a greedy rule to make its choice. Once a choice is made the algorithm never changes its mind or looks back to consider a different perhaps better solution; the reason the algorithm is called greedy. In comparison with for example dynamic programming, discussed in chapter 'Optimization models', a greedy algorithm may fail to find the optimal solution, though it usually finds a pretty good one, and runs much faster than an algorithm using dynamic programming.

Simulated annealing
Simulated annealing can be defined as a biased random walk that samples the objective function in the space of independent variables. It has the ability to migrate trough a sequence of local optima in search of a global optimal solution and to recognize when the global extreme has been reached. This technique is a generalized heuristic algorithm which can handle large class of problems irrespective of the nature of the objective function in the case of classical techniques.

Genetic algorithms
Genetic algorithm is being used in a variety of applications. It is a search and optimization procedure that is motivated by the principle of natural genetics and natural selection. It is based on the survival of fittest principle which tries to retain those species which are more suitable under the prevailing conditions. Only the best offspring of the solutions are retained for the next generation of mating; subsequent generations

proceed in an evolutionary fashion. The fittest solution which has been evolved is considered to be an optimal solution.

Artificialn natural networks
With artificial networks human brain activities can be modelled in a mathematical way. In this way diverse neural networks are developed for different combinatorial problems. Artificial neural networks are providing new approaches to problem solving. The key to utility of artificial neural networks is that they provide a computational model that can be used to systematize the process.

Tabu search
Tabu search is an iterative procedure designed for the solution of optimization problems. The basic idea of the method is to partially explore the search space of all feasible solutions by a sequence of moves. At each iteration, the move carried out is the most promising among those available. A mechanism which forbids a set of moves at each iteration is present, aiming to help the algorithm to escape from local (but not global) minima.

Input
The input of heuristic models is comparable with input for optimization models.

Output
The output of heuristic models is a suboptimal solution dependent of the problem. The output can for example be an alternative that can be chosen.

Assumptions
The assumptions are also dependent on the kind of problem.

Advantages and disadvantages
An advantage of heuristic models in stead of analytical ones is the simplicity. In general the computation time of heuristics is much less than of analytic optimization techniques. An important disadvantage is the (probable) sub optimality of the solution.

Application
Mostly heuristics will be used when an analytical approach is too complex.

Track record TNO

Drama theory

Description
Drama theory addresses problems involving multiple parties with conflicting objectives. Drama theory is a variant of game theory. In game theory a mission is clear and the theory is based on rational choices where assumptions and preferences have to be stated in advance and will not be changed in time. Drama theory takes into account the way people play games at different levels at the same time (what they say, what they mean, and what they do). With Drama theory players can show irrational and emotional behaviour and its purpose is to learn how emotions and reasons are used to change assumptions and preferences. When communication is not possible between the parties, drama theory will be reduced to game theory.
Confrontations are the principal element of dramas. A confrontation contains a number of parties involved in the conflict, each of whom holds a particular position. A peace support operation can be seen as a linked sequence of confrontations. Confrontations

are effectively handled by a technique known as Confrontation Analysis. This is a method that applies Drama Theory. It considers the way players apply rational-emotional pressure on each other to redefine the game *prior* to it being played. The process of applying pressure is called a confrontation. A player 'wins' a confrontation by forcing or persuading others to redefine the game so that it has an agreed solution in line with the player's objectives.
With drama theory the process can be seen in Figure C.1. This process is used in the development of scenarios.

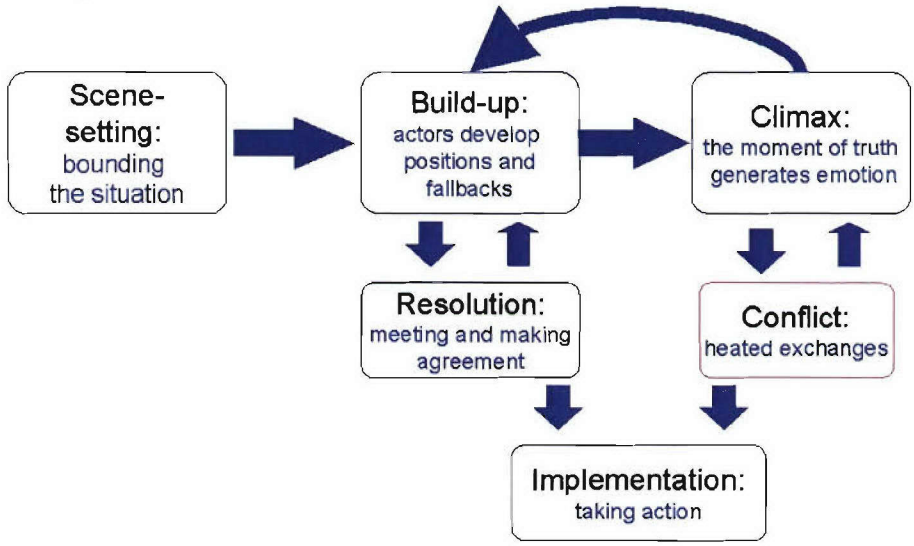

Figure C.1 Process Drama Theory.

With each conflict the above cycles can be passed through.
The different phases in the above figure are defined as follows:

- Scene setting: analysis of the parties, goals, behaviour and strategies. This is all based on expectations and till this point there is now difference with game theory.
- Build-up: having conversations and finding out each others strategies, goals and payoffs.
- Resolution: in this phase the parties are working out the details where possible conflicts become clear. When the strategies suit each other and there is no conflict, this phase will go fast but when a conflict arises they will go back to the build-up phase.
- Climax: if there is a conflict, the parties can influence and steer each other. A change in strategy or preferences of one of the parties has to take place to solve the conflict.
- Conflict: the conflict has not been solved. The parties break up and they have to decide if they actually execute the threats.
- Implementation: in this phase the actions are taken place. They can't be turned backwards.

Advantages and disadvantages
Historically, drama theory has its roots in game theory, but has been developed to overcome many of the weaknesses encountered in game theoretic treatments of problems. In particular, the advantage of drama theory is that it removes the stifling assumptions of fixed situations and rationality of game theory.

Application
Applications can be found in operational analysis of peace support operations, politics, psychology and economics.

Track record TNO
[1] Scenario Development; Toevank; S020279.
[2] SPECTRUM.
[3] http://www.dodccrp.org/events/1999/1999CCRTS/pdf_files/track_6/043howar.pdf
[4] http://www.ima.org.uk/conflict/papers/Bryant.pdf
[5] Confrontation Analysis by Nigel Howard.
[6] Expert group scenario development: http://intra.fel.tno.nl/sv/0015/SV-000062/_intranetdata/cd-rom_versie1.0/start.html

Quantitative threat assessment: static and dynamic analyses

Description
This chapter describes techniques to quantify military threat. Threat can be defined as: any direct or indirect action by other countries which conflicts with the interests of a country. The threat can be economic, social, political, ideological or military.
When a military threat exists, a country will develop a strategy to decrease or remove the threat. Of course, the measure of threat is highly important. There are techniques necessary to quantify the threat.

Static analysis
In this analysis threats are compared on the basis of number of weapons and personnel of the forces. These techniques are input oriented and give an idea of the combat strength-relationship of the two parties. The consequences of this relationship on the course of the fight are not analysed (see dynamic analysis). This has to be assessed by experts using their experience and using historical data. Some static methodologies are described below:
Bean count method: this method just compares the amount of weapons and the soldiers.
Weapon effectiveness index (WEI) or Weapon Unit Value (WUV): this method determines the power score of a weapon system in a subjective way, by weighing the attributes and give them a score.
Potential Anti-potential method: determines the power score of a weapon system in an objective way, by using attrition rates from simulation models. The value of the weapon system can be calculated because it is proportional to the measure where the weapon can eliminate an enemy goal.
Force potential using operational lethality indices (OLI): this method determines the force potential on the basis of power scores
Situational Modified Force Strength method (SMFS): this method determines the force strength on the basis of the WEI per weapon. The capacities, anti-capacities, deficits in capacities and deficits in anti-capacities of certain combat functions and scenario aspects, like terrain and organisation of the units, are taken into account.

Dynamic analysis
Dynamic models, uses force strengths or force potentials in a simulated scenario to obtain the casualties suffered or/and the territory gained or lost. These models are output oriented and use mainly the results of static methods as input. With these techniques an idea is given of the consequences of the conflict. The next four methods are dynamic analysis:

- Quantified Judgment Method of Analysis (QJMA): determines the number of wounded persons at both sides, using the results of the static method Force Potential using Operational Lethality Indices.
- Situational Force Scoring (SFS): determines the attrition rates at both sides, the exchange rate, the FLOT movement rate and the number of wounded persons per combat function, using the results of the static method SMFS.
- Adaptive Dynamic Model (ADM): determine the Force Strength Losses of two parties a day, where the varying attrition rates and supplementations are taken into account. The also varying threshold (lower limit of force strength) determines when the attacker or defender surrenders.
- Arms Race Models: this method gives the construction of the arsenal in the course of time of two countries which are dependent of each other.

Input
The consequences of the combat strength relationship of the two parties on the course of the fight are not analysed with static analysis. This has to be assessed by experts using their experience and using historical data.
Dynamic models are output oriented and the results of static methods can be used as input.

Output
Static models are input oriented and the results can be used for dynamic methods.

Assumptions
To find out the threats to a country the interest or objectives of the country should be clearly understood.

Disadvantage of static approach
The basic problem of static analysis is that it does not provide any information that would help the analyst or decision maker in assessing the threat or security implications of the combat power of opposite force postures in given situations. The experts need to have experience or well documented empirical evidence that permits them to assess the static analysis results by applying a judgmental model of combat processes residing in their brains.
The static analysis models require a supplement in the form of mental appreciation of the outcomes based on past wars and current force rations. This is subjective and the conclusions may become controversial in some cases. The dynamic analysis models are too detailed and adequate information on weapons and tactics may not be built up in the models. Thus they may not represent all the complexities of the real world situations.

Application
The quantification of certain threats gives a country a strategy and the possibility to assess if the country can resist this threat. Using techniques to determine the weapon effectiveness, the force strength of a unit and the waste during a conflict, are also applicable with:
- Combat simulation models: to model the weapon effectiveness and the waste.
- Policy studies: an aid by determining required units to win a certain conflict. With this study the consequents of a certain conflict are analysed departing form a certain available arsenal and personnel.

Track record TNO
[1] Defence Requirement Review (DRR); NC3A.
[2] ACROSS; Klein Baltink; S200042.

Belief networks and influence diagrams

Belief networks and influence diagrams analyse the relationship between different elements. They are used to graphically combine uncertain and dependent events and decisions. Influence diagrams can be seen as an extension of belief networks.

Belief networks
A Belief Network is a directed, acyclic network built up with nodes and arcs. An acyclic network means that in the network there is no possibility to return from a certain node to this node again. Every node (also called a chance node) is representing an uncertain event. If there is an influence (or dependence) from one node to another, this will be described by an arc (also called influence arc). Using these elements, a Belief Network can be extended up to a large number of nodes. Between every pair of nodes there can exist an arrow. Combined, the whole network is a representation of the uncertainty of the events in the network and represents a complete distribution of probability.
A simple example of a Belief Network is given in Figure C.1. In this, the uncertainty is represented as the introduction of a new product: it will be successful ('Success') or not. Given that the event is successful or not, an expert produces a prediction about the reaction of the market ('Prediction'), for example good, average or bad. The example contains two uncertain events, presented with an ellipse: 'Success' and 'Prediction'. The arc between the variables 'Success' and 'Prediction' indicates that these events are dependent of each other. Because of the arc, the node 'Prediction' is called a child of the node 'Success' and the node 'Success' is called a parent of the node 'Prediction'.

Figure C.2 A simple Belief Network.

A Belief Network is used to illustrate uncertain factors, where the emphasise is on the carrying through of information known in the network. New information changes the probability and can therefore be used to determine a new strategy. Belief Networks can be applied qualitatively and quantitatively. Qualitatively, it can be used as an illustration of the interaction of the underlying problem. Then, it will be used as a representation of the causal structure of a problem or model. If a problem is only qualitative, it is called a Qualitative Probabilistic Network (QPN) or Qualitative Certainty Network (QCN) in stead of a Belief Network. Just like influence diagrams, Qualitative Probabilistic Networks and Qualitative Probabilistic Networks can be seen as derivatives of belief networks.
A Belief Network can also be used to present a quantitative relation in a network. The quantitative relations in a Belief Network are represented by assigning a discrete distribution of probability to each node. This probability describes the possibility of the different outcomes of the events in the node and is conditionally on the parent of that node.

Influence diagrams
Influence Diagrams are used when the goal is to determine the optimal choice from different (uncertain) alternatives. This optimal will be reached if the alternative has the highest benefit or the highest profit. The input of the influence diagrams can either be from experts or from empirics or a combination of these. Just like a Belief Network, an Influence Diagram is a graphical representation of a direct, acyclic network. However

with Influence Diagrams, the nodes in the network can, besides uncertain events, also present other types of variables, namely decisions or usage value. In an Influence Diagram four kinds of notes can be found:

- Decision nodes: form: rectangle. The node can take different values which represent the possible decisions of the decision maker.
- Chance nodes: form: oval. These represent uncertain events which influence the decision nodes.
- Deterministic nodes: form: double oval. The value of these nodes is determined algebraically ascertain from their (direct) parents. In other words: if the value of the parents of a deterministic node is certainly known, the value of the deterministic node is also with certainty known.
- Value/utility nodes: form: diamante or rectangle with rounded angles. The value of the value/utility nodes has been linked with the different possibilities which come from the parents. The meaning of a value node can differ from a profit to a measure of satisfaction.
  The form of the nodes can differ per software package. There are two kinds of arcs possible in an Influence Diagram: influence arcs and information arcs. The influence arcs have the same meaning as the arcs in the Belief Network, namely that the event the arc is going to is dependent on the event which the arc comes from. However, information arcs are going to a decision node and indicate that the decision has to be taken, as soon as the values of the direct parents are known. The parents of the decision nodes are dated. This is called 'temporal precedence'. If there are more decision nodes in the network, these have to be committed by information arcs so that the different decisions are made in a fixed order.

The example of Figure C.3 can be extracted as follows:

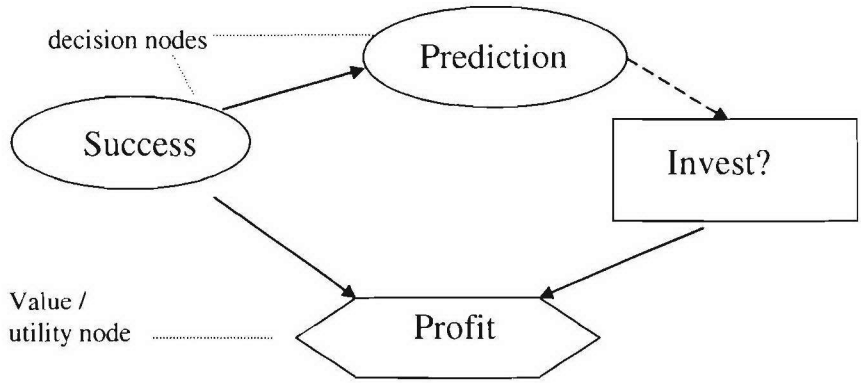

Figure C.3 Example of an influence diagram.

As soon as it is known what the market reaction will be (good, average or bad) the decision has to be made if one will or will not invest further in the product.
An example of the usage of Influence Diagrams is the 'counter proliferation; of the US, i.e. the potency to resist 'Weapons of Mass Destruction'. This is a study of the suitability of different possible Counter proliferation Systems in the US. An influence diagram can be drawn where the influences of the suitability of the different weapon systems are mapped.

Input
The input of belief networks and influence diagrams can be the prediction of an expert or can come from empirics. In the previous example the input will be about the reaction of the market.

Output
Belief networks are used to map uncertain factors. Output of a belief network will consist of (conditional) chances. Influence diagrams are used when the emphasis is on determining the optimal choice between different uncertain alternatives. The output will be which alternative to choose given the assumptions.

Assumptions
The next assumptions are made for belief networks or influence diagrams:
The arcs are converted in conditional chances for a certain event. This conversion is only legitimately if the network satisfies the Markov property that a node is just dependent of his parents. This Markov property can be expressed by the concept of *conditional independence*. Events A and B are conditionally independent given event C, if

$P(A \mid C)$ is independent of $P(B \mid C)$

In case of series of events without branching, this definition is equivalent with a standard Markov chain, where

$$P(A \mid B, C) = P(A \mid B)$$

Where event A is a child of event B and event B is a child of event C (C → B → A).
The belief network or influence diagram has to be a directed network, so that it is clear which event comes before another.
The network has to be acyclic. This means that there is no way to go through the network from a node back to the same node.

Advantages and disadvantages
Belief Networks and influence diagrams make it possible to quantitatively model a combination of uncertain factors. The visual representation can make aspects of the problem very clear. Constructing such networks will force the model maker to think about the dependency between events in a structured manner.
One of the most important aspects and big advantage of a Belief Network is that information known for an event can be directly used in the network. This means that as soon as the outcome of an event has become certain, it is possible to calculate all conditional chances of the children.

Application
For people without a mathematical background (and sometimes even for people with a mathematical background) consideration of this dependency is a complex factor. Mostly a decision maker tries to take the factors which influence the problem into account, but mutual dependence between factors are often (mistakenly) left aside. So to use this method, it is at least advisable to have some mathematical and probabilistic experience.

Track record TNO
[1] DPL.
[2] B.W. Wisse, *Het modelleren van Crisisbeheersingsoperaties*, FEL-03-S228, Januari 2003, TNO-FEL.

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15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

One of the primary goals of the Netherlands Armed Forces is to have at their disposal units that are adequately equipped and outfitted to carry out tasks across the complete range of peace-supporting missions, varying in levels of hostility. To this end a scientific research program was formulated which encompasses a number of projects which focus on various aspects of operations of teams of dismounted soldiers. The aim of this project is to identify scientific methods and models which facilitate the measurement of operational effectiveness of dismounted small units. Measuring operational effectiveness of dismounted small units requires the use of methods models and simulations. Within this project we have made an inventory of the available methods and models within the TNO technology portfolio. In order to be able to asses the usefulness of these methods and models for the tasks the dismounted small units are confronted with, the task decomposition developed in the project Small unit tactics in peace keeping operations' (Smeenk et al., 2004) was used as a guideline. The usefulness of the methods and models was established by classifying these into three categories, i.e. logically possible, theoretically feasible and practically applicable. For each of the tasks the models and methods were reviewed with respect to the mentioned categories. This resulted in one matrix of tasks and models/methods.
The analysis of the matrix suggests that not one single method/model is practically applicable to all the identified tasks of the dismounted small unit. Furthermore, although TNO has access to a range of models/methods which are practically applicable to a number of tasks, these tasks can al be considered as high intensity tasks. TNO does not have access to methods/models which are explicitly and practical applicable in the low intensity range of the task spectrum.
A small number of models seem to have the potential to fill the identified gap.

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